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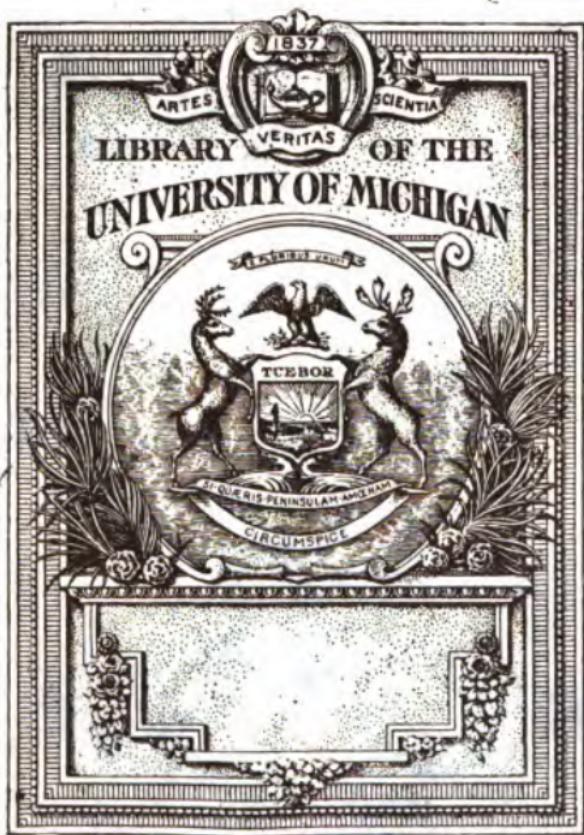
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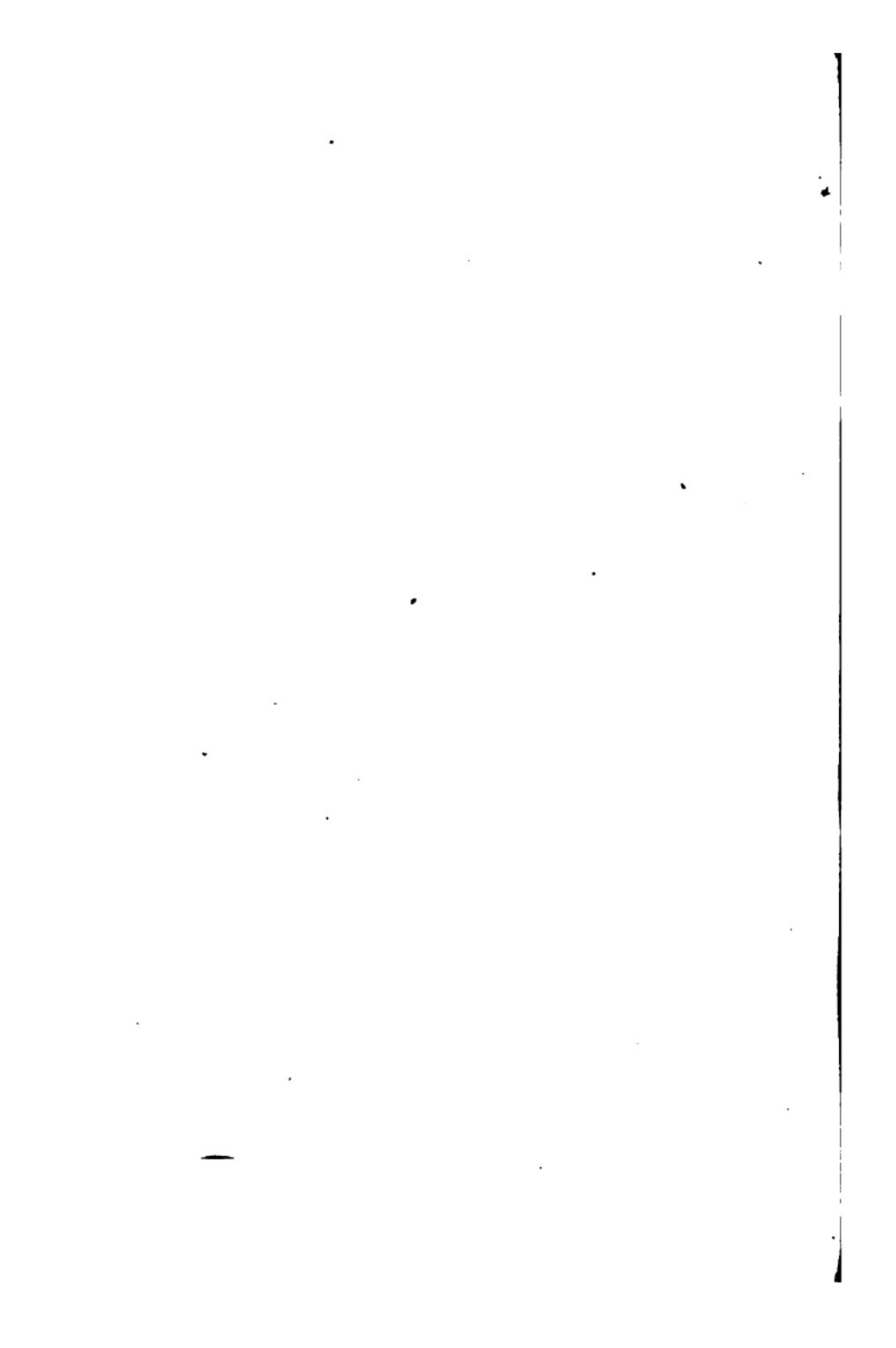
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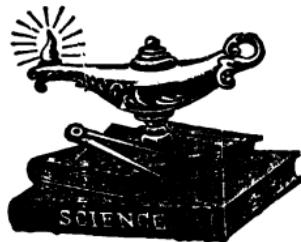
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Machine-Shop Arithmetic

SHOWS HOW ALL, SHOP PROBLEMS ARE WORKED OUT AND "WHY." INCLUDES CHANGE GEARS FOR CUTTING ANY THREADS; DRILLS, TAPS, SHINK AND FORCE FITS; METRIC SYSTEM OF MEASUREMENTS AND THREADS. USED BY ALL CLASSES OF MECHANICS, APPRENTICES, ETC., ETC.

— BY —
FRED. H. COLVIN AND
WALTER LEE CHENEY



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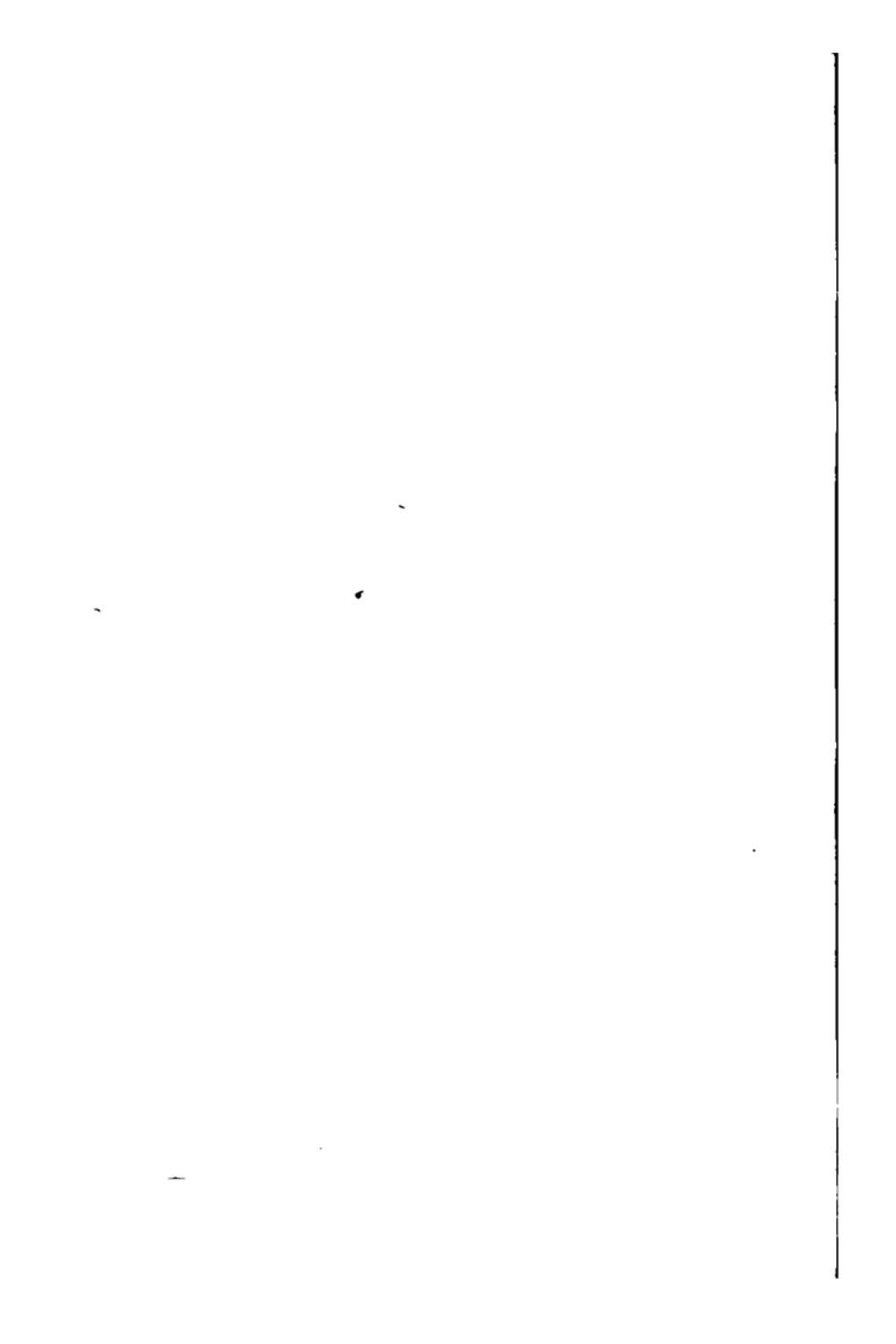
PREFACE.

It was thought that a book of convenient size, containing examples of simple mathematical calculations which come up every day in the work of practical men (a portion of which was originally published in *Machinery*), together with methods of solving the problems, and *explanations in clear language of the principles on which the methods of solution are founded*, would be appreciated by those whom it is intended to serve.

The demand for this little book has continued to such an extent that we have revised and enlarged it so as to bring it up to modern practice in every particular.

The Authors.

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MACHINE-SHOP ARITHMETIC.

Chapter I.

Decimals.

There are few men who do not understand vulgar or common fractions, as it is plain that $\frac{1}{2}$ means one-half, $\frac{3}{8}$ means three-eighths, etc., and in plain language we say that the figure below the line (or denominator) shows the number of parts into which the number (or whatever is being considered) is divided, and the figure above the line (numerator) shows how many of these parts are being spoken of.

Decimals or decimal fractions are a *system* in which ten is the base (derived from *decem* meaning *ten*), and is not a fundamental principle.

In this everything is reduced to tenths, hundredths, thousandths, etc., and the value is determined by the position of the decimal point.

Taking the number .125 and we read the first figure as tenths, second as hundredths, etc. ; and as there are three figures the value must be 125 thousandths or $\frac{125}{1000}$, the position of the point indicating the value of the decimal fraction.

Moving the point between the 1 and 2 we have 1.25, which makes 1 a whole number and $\frac{25}{100}$ the fraction.

Moving it again in the same direction we have 12.5 or 12 and $\frac{5}{10}$. We see then that moving the point to the *right* multiplies by ten for every place it is moved (and consequently that moving it to the left would *divide* by ten in a similar manner), and that we can divide or multiply by ten by simply changing the position of the point.

If we have common fractions it is very easy to change them to decimals by dividing the numerator by the denominator, as in the case of $\frac{1}{2}$ we have $2)1.000 = .500$ or $\frac{5}{10}$.

Take the numerator and place a decimal point after it, adding as many ciphers as are likely to be needed, four being a very common number to add, as four de-

cimal places (or ten thousandths) are usually accurate enough for most calculations.

When we have $\frac{1}{64}$ to reduce to decimals it is simply an example in long division, the placing of the point being the main thing, and we simply divide 1.0000 by 64 which equals .0156 or 156 *ten thousandths*.

It should be thoroughly understood that there is no *principle* involved in using this point, it is merely a custom or system (although a very useful one), but as we find time tables in which 9.10 means ten minutes past nine, although ten minutes equals $\frac{10}{60}$ instead of $\frac{10}{100}$ as in the case of decimals, we see this is always a custom and not a fundamental principle.

Although it is customary to use common fractions in many shops, the use of finer measurements, such as hundredths and thousandths, makes it convenient to have a table showing the fractions ordinarily used and their equivalents in decimals, and a table of this kind is given at the end of this chapter.

Knowing that all figures to the right of the decimal point are decimal parts of

one (no matter what) and that all figures to the left are whole numbers it will be readily seen that in addition and subtraction we place the figures so that the decimal points come under each other, as,

Adding	or subtracting
2.1347	4.3257
2.2532	2.17857
<hr/>	<hr/>
4.3879	2.14713

Never mind the number of figures in the decimal, place the points in line, add ciphers (either mentally or in reality) to make them even, and proceed as in ordinary calculations.

In multiplication we pay no attention to the relative positions of the decimal points, but multiply as usual and point off in the product as many places as there are decimals in *both* the multiplier and multiplicand, counting from the *right*.

As an example we have 3.125 multiplied by 1.25, or,

$$\begin{array}{r} 3.125 \\ 1.25 \\ \hline 15625 \\ 6250 \\ 3125 \\ \hline 3.90625 \end{array}$$

There being three places in one and two in the other we count off five (two plus three) from the *right* and place the point between the 3 and 9, making the result 3 and $\frac{90625}{100000}$.

The reason for pointing off in this manner will be clear if we study the question a little. Taking the example above we find the whole numbers to be 3 and 1 and it is evident that the result cannot be either 0.390625 or 39.0625, but must be more than 3 and less than two figures, as in the last number above.

Taking the numbers 3.9×4.8 it is evident that the answer will be more than $3 \times 4 = 12$ and less than $4 \times 5 = 20$, as the numbers are less than 4 and 5.

$3.9 \times 4.8 = 18.72$ with two figures pointed off in accordance with both rule and reason.

It has probably been noticed that in placing the denominators under decimals (in order to make their value clear) we put a figure 1 at the left and as many ciphers to the right as there are figures in the decimal.

In the case first mentioned we place

five ciphers to the right of the point, making it "hundred thousandths."

We have given these denominators to make the value of the decimal more clear, although in actual practice it is never done, the value being easily reckoned mentally by calling the point 1, and adding ciphers as before stated.

Division of decimals is very easy, after you learn to neglect the decimal point while you are dividing, and then to put it in the right place in the quotient (or answer).

Divide as with simple numbers and point off as many places in the quotient (answer) as the decimal places of the dividend (number divided) exceeds the decimal places in the divisor.

If the decimals in the divisor exceed those in the dividend, add ciphers to the right of the dividend as far as necessary, taking care to count only those *used*, when placing the decimals in the answer.

Division being the reverse of multiplication it seems almost self-evident that pointing off should also be reversed.

If the reasons given before are tho-

roughly understood this will be made plain without difficulty.

Divide 3.24 by 1.2.

$$\begin{array}{r} 1.2)3.24(2.7 \\ 24 \\ \hline 84 \\ 84 \\ \hline \end{array}$$

And as there are two decimal places in the dividend and only one in the divisor, we point off one place from the right in the answer.

Take another case and divide 3.1478 by .071

$$\begin{array}{r} .071)3.1478(44.3+ \\ 284 \\ \hline 307 \\ 284 \\ \hline 238 \\ 213 \\ \hline 25 \end{array}$$

Forget all about the decimal points in the divisor and proceed as before. Then as there are three decimal places in the divisor and four in the dividend we point off one from the right and have 44.3 for an answer. This can be carried further by adding ciphers to the dividend, which will

evidently not alter the *position* of the decimal point in the least, but will simply carry the answer to more decimal places.

Not wishing to carry the division to more decimal places and as it does not come out even we put a plus sign (+) after the quotient, showing that it is incomplete.

It does not matter if the divisor is larger than the dividend, as in dividing .00287 by .0921

$$\begin{array}{r} .0921).002370000(.25732+ \\ 1842 \\ \hline 5280 \\ 4605 \\ \hline 6750 \\ 6447 \\ \hline 3030 \\ 2763 \\ \hline 2670 \\ 1842 \\ \hline \end{array}$$

We add four ciphers and make nine decimal places in the dividend, and as these exceed the decimals in the divisor by five places we must point off five places from the right and place the point before the 2.

If you have any doubt as to its correctness, multiply the answer by the divisor and the result should give the dividend.

It is well to prove work in this way if you have any doubts in the matter.

To divide .3987 by 125.2

$$\begin{array}{r} 125.2) .3987000 (.003184 + \\ 3756 \\ \hline 2310 \\ 1252 \\ \hline 10580 \\ 10016 \\ \hline 5640 \\ 5008 \\ \hline 632 \end{array}$$

We have added three ciphers to the dividend, making seven decimal places, and as there is but one decimal place in the divisor, the quotient must have seven minus one, or six places. As there are but four figures in the quotient we must make the six by adding two ciphers to the left (in front) of the quotient and placing the point in front of the ciphers, making the answer .003184. It will be seen that placing ciphers to the right would not alter the value of the decimal in the least.

Divide .96 by .08

$$\begin{array}{r} .08) .96(12 \\ 8 \\ \hline 16 \\ 16 \\ \hline \end{array}$$

As the number of decimal places in both dividend and divisor are equal, the point would come after the 12 and would of course be useless.

Divide 4.5 by 12.2

$$\begin{array}{r} 12.2) 4.5000(.368+ \\ 366 \\ \hline 840 \\ 732 \\ \hline 1080 \\ 976 \\ \hline 104 \end{array}$$

As there are four decimal places in dividend and one in the divisor we point off three places, which brings the point before the 3 as shown.

Table of decimal equivalents on next page.

DECIMAL EQUIVALENTS OF AN INCH.

		$\frac{1}{4}$	.25	$\frac{1}{2}$	.5	$\frac{3}{4}$	.75
$\frac{1}{64}$	.015625	$\frac{1}{64}$	.265625	$\frac{33}{64}$	.515625	$\frac{49}{64}$	.765625
$\frac{1}{32}$	.03125	$\frac{9}{32}$	.28125	$\frac{17}{32}$	.53125	$\frac{25}{32}$	.78125
$\frac{3}{64}$	.046875	$\frac{19}{64}$	.296875	$\frac{35}{64}$	.546875	$\frac{51}{64}$	.796875
$\frac{1}{16}$	.0625	$\frac{5}{16}$	.3125	$\frac{9}{16}$	.5625	$\frac{13}{16}$	.8125
$\frac{5}{64}$	.078125	$\frac{21}{64}$	.328125	$\frac{37}{64}$	.578125	$\frac{53}{64}$	.828125
$\frac{3}{32}$	.09375	$\frac{11}{32}$	.34375	$\frac{19}{32}$	.59375	$\frac{27}{32}$	.84375
$\frac{7}{64}$	.109375	$\frac{23}{64}$	.359375	$\frac{39}{64}$	.609375	$\frac{55}{64}$	.859375
$\frac{1}{8}$	.125	$\frac{3}{8}$	.375	$\frac{5}{8}$	.625	$\frac{7}{8}$	.875
$\frac{9}{64}$	.140625	$\frac{25}{64}$	.390625	$\frac{41}{64}$	.610625	$\frac{57}{64}$	.890625
$\frac{5}{32}$	.15625	$\frac{13}{32}$	.40625	$\frac{21}{32}$	.6625	$\frac{29}{32}$	.90625
$\frac{11}{64}$	.171875	$\frac{27}{64}$	.421875	$\frac{43}{64}$	.671875	$\frac{59}{64}$	.921875
$\frac{3}{16}$	.1875	$\frac{7}{16}$	.4375	$\frac{11}{16}$	.6875	$\frac{15}{16}$	.9375
$\frac{13}{64}$	.203125	$\frac{29}{64}$	.453125	$\frac{45}{64}$	.703125	$\frac{61}{64}$	.953125
$\frac{7}{32}$	.21875	$\frac{15}{32}$	.46875	$\frac{23}{32}$	.71875	$\frac{31}{32}$	.96875
$\frac{15}{64}$	.234375	$\frac{31}{64}$	.484375	$\frac{47}{64}$	.734375	$\frac{63}{64}$	.984375

Chapter II.

Conventional Rule for Square Root.

(For explanation of principle on which the rule is founded see chapter beginning on page 72.)

Separate the given number into periods, by pointing every second figure, beginning with the unit's place.

Find the greatest square in the left hand period and place its root on the right; subtract the square of this root from the first period and to the remainder bring down the next period for a dividend.

Divide this dividend, omitting the last figure, by double the root already found, and annex the result to the root and also to the divisor, multiply the divisor as it now stands, by the figure of the root last obtained, and subtract the product from the dividend.

If there are more periods to be brought down, continue the operation in the same manner as before.

Example:

What is the square root of 144?

$$\begin{array}{r} \cdot \cdot \\ 144(12) \\ 1 \\ \hline 22 \quad \left| \begin{array}{r} 44 \\ 44 \end{array} \right. \end{array}$$

The greatest square in the left hand period or 1, is 1. Subtracting leaves nothing and bringing down the next period gives 44 for the new dividend. Doubling the root already found gives 2 for a trial divisor and trying this in the first figure of the new dividend gives 2 for the next root figure. Annexing this to the trial divisor gives 22 for the true divisor and multiplying by 2 gives 44, coming out even in this case. Sometimes several trials are necessary.

Chapter III.

Conventional Rule for Cube Root.

(For explanation of principle on which the rule is founded, see chapter beginning on page 85).

Separate the given numbers into periods, by pointing every third figure, beginning with the unit's place.

Find the greatest cube in the left hand period and place its root on the right; subtract the cube of this root from the left hand period and to the remainder bring down the next period for a dividend.

Divide this dividend, omitting the last two figures, by three times the square of the root already found; annex the quotient to the root.

Add together the trial divisor, with two ciphers annexed, three times the product of the last root figure by the rest of the root, with one cipher annexed; and the square of the last root figure.

Multiply the divisor, as it now stands,

by the figure of the root last obtained, and subtract the product from the dividend.

If there are more periods to be brought down, continue the operation in the same manner as before.

Example:

What is the cube root of 1728?

$$\begin{array}{r} 1728(12 \\ 1 \\ \hline 728 \\ 300 \\ 60 \\ 4 \\ \hline 364 \\ 728 \\ \hline \end{array}$$

By following the rules closely in the manner illustrated in the square root example, there will be no difficulty in understanding the operation.

Chapter IV.

Formulas.

As it is well to become familiar with the tools we are to use, the following signs are given, with their meanings, before we proceed to use them.

π called "pi" = 3.1416, which is the circumference of a circle whose diameter is 1. This can be 1 inch, 1 foot or 1 mile, and the circumference will be 3.1416 inches, feet or miles as the case may be.

$d^2 = d$ squared or multiplied by itself.

$d^3 = d$ cubed or multiplied by itself twice, $d^4 = d$ fourth, etc.

The small figures at top are called exponents.

$\sqrt{}$ = square root and denotes that the square root is to be extracted from the number following it; when bar extends over other figures, it applies to all beneath it, thus $\sqrt{2+7}=3$ (square root of sum.) This can also be represented by $\sqrt{(2+7)}=3$ as before, the brackets showing that all

within them are to be taken as one quantity. $\sqrt[9]{9+2}=3+2=5$, as the root is only taken from first figure because the sign does not extend over the other figures.

$\sqrt[3]{}$ =cube root, $\sqrt[4]{}$ =fourth root,
 $\sqrt[5]{}$ =fifth root, etc. Fourth root can be found by extracting square root twice.

\therefore =Therefore.

The signs must be carefully watched, as all depends on interpreting them correctly; care will do this, however, and strict attention should be paid to it.

Formulas are such a useful feature in the arithmetic of the mechanic, or perhaps it would be more correct to say abbreviation or condensation of the arithmetic, that they should be better known and appreciated by him, as they will shorten his calculations and help him to become much more familiar with the rules used in standard practice among mechanics and engineers. Knowing from a fairly long shop experience that shopmen as a rule seem to have a horror of all formula, imagining them difficult or puzzling and

only useful in confusing those who have not had opportunities in mathematical education, we wish to show how useful formulas are, how they shorten calculation, how they economize space, and that they are much more convenient to remember than long-winded rules, and wish to make them clear even at the risk of being too elementary in the explanations. There seems no better way of making their simplicity evident than by showing how they are *made*, how they are *used*, and their *advantages*, ending with illustrations from everyday practice.

To begin with, a formula is simply an arithmetical rule in which all words are omitted, all the quantities represented by letters and figures, and all the operations are indicated by signs and by the position of the different characters.

We learn from our arithmetic that the area of a rectangle (a figure whose opposite sides are parallel and whose angles are right angles) is found by multiplying one side by the other, or calling one side A and the other B, we can say "A multiplied by B equals the area." To go a

little farther, to call $A=10$ inches, $B=20$ inches, then the area will equal $A(10) \times B(20)=200$ square inches.* To state this correctly we say:

Let $A=\text{short side of rectangle.}$

“ $B=\text{long}$ “ “ “

“ $C=\text{area}$ “ “ “

Then $C=A \times B.$

As one of the handy features of all formula is the ease of transposition, or of changing the “rule” to find any one quantity, the others being given, we can show this nicely in this simple case and shall do so as we proceed with other problems. We might have the area and the short side given to find the long side or the area and long side given to find the short side. Then as $C=A \times B,$

*It is evident that the area will be in square measure of whatever unit the sides are; in this case square inches. The multiplication sign is not necessary between letters, as A and B in this case, and is often omitted, $C=A B$ meaning that $C=\text{product of } A B.$ In some English works multiplication is denoted by a period where we usually place the decimal point, their decimal point being placed half way up the figure as $A.B$ means $A \times B$, while $3.5=3.5$ or $3\frac{1}{2}.$

$$B = \frac{C}{A} \text{ and } A = \frac{C}{B},$$

or in figures, $C=10 \times 20=200$, $B=\frac{200}{10}=20$ and $A=\frac{200}{20}=10$. Going now to another case we take the circle and learn that the relation between the diameter and the circumference is as 1 to 3.1416 (near enough for practical purposes), or in other words, that a circle 1 inch in diameter has a circumference of 3.1416 inches, or one of 2 inches has a circumference of 6.2832 inches, so we say: Diameter (d) multiplied by 3.1416 equals circumference in the same measure or unit as the diameter, or $d \times 3.1416 = c$ or circumference. This relation has come to be known as "pi" and represented by π , which means that the sign π stands for the number 3.1416 as $\pi d = 3.1416 \times \text{diameter}$, which of course equals the circumference or periphery. Having a pulley 10 inches in diameter, making 200 revolutions, per minute, we wish to find how fast the rim is traveling in feet per minute. The circumference equals 10×3.1416 (diameter $\times \pi$) = 31.416 inches, which, divided by 12, gives 2.618 feet. Now to make our formula we say :

d =diameter in inches.

$\pi=3.1416$.

c =circumference in inches.

Then $d \times \pi = c$ or $\frac{d \times \pi}{12} = c$ in feet.

As it is running 200 revolutions per minute, $200 \times 2.618 = 523.6$ feet per minute, or combining this in the formula and adding r =revolutions per minute and F =feet per minute that rim travels, to above notation we have

$$F = \frac{cr}{12} \text{ or,}$$

$$F = \frac{d \times \pi \times r}{12} \text{ or } \frac{d \pi r}{12} \text{ or } \frac{cr}{12} =$$
$$\frac{10 \times 3.1416 \times 200}{12} \text{ or } \frac{31.416 \times 200}{12} = 523.6$$

feet per minute.

This can be transposed to find any of the quantities and as we wish to be thorough in all we do, we transpose as follows:

$$c = d \times \pi, \text{ and } d = \frac{c}{\pi}, \quad F = \frac{d \times \pi \times r}{12} \text{ or } d = 12 \frac{F}{\pi \times r}$$

because, d being in inches and F in feet,

it is evident that the speed in feet, divided by "pi" times revolutions, must be multiplied by 12 to reduce it to inches. Then

$$r = \frac{F \times 12}{\pi \times d} = \frac{523.6 \times 12}{3.1416 \times 10} = \frac{6283.2}{31.416} = 200$$

and with these three transpositions of the formula any desired factor can be obtained.

Taking the area of the circle next we learn that the diameter squared (multiplied by itself) and multiplied by the constant number .7854 gives the area. The area of a cylinder 12 inches in diameter will then be $12 \times 12 \times .7854 = 113.09$ square inches; calling the diameter d , and a the area, we say $d^2 \times .7854 = a$.

What is the total pressure on a steam piston 10 inches in diameter, steam pressure 100 pounds per square inch? In this case $d=10$, then $d^2 \times .7854 = 10 \times 10 \times .7854 = 78.54 \times 100 = 7854$ pounds total pressure on piston. Now taking a cylinder twice this diameter, with the same pressure, we then have $20 \times 20 \times .7854 = 314.16 \times 100 = 31,416$ pounds of total pressure, or *four times* the former case, although the diameter is only *twice* as

large. This brings us to the "law of squares," which is simply that *areas of similar figures vary as the squares of similar dimensions*, diameter in this case, the other cases will come later. This shows that in any cylinder, tube or shaft, the areas vary as the square of the diameters, and that a 2 inch tube has four times the area of a 1-inch tube, or a 3 inch cylinder has 9 times the area of a 1-inch cylinder (because $3 \times 3 = 9$, while $1 \times 1 = 1$), while the areas of two holes, 3 and 5 inches respectively, are as $3 \times 3 = 9$ and $5 \times 5 = 25$, or as 9 is to 25, or if one will pass 9 cubic feet of air or water per second, the other will pass 25.

Having found the area of a shaft, we have only to multiply this by the length to find the volume of cubical contents, and knowing this, we can estimate very closely the weight of different substances, by multiplying the number of cubic inches it contains by the weight of one cubic inch of the material.

Putting this into a short formula we have:

d =diameter in inches.

l
 $l = \text{length in inches, or } \frac{l}{12} = \text{length}$
in feet.

$c = \text{constant.}$

Then $d^2 \times .7854 \times l \times c = \text{weight of}$
any round shaft or bar.

What will a steel shaft 2 inches in diameter and 10 feet long, weigh? Referring to table of weights of metal in Kent's Pocket Book, we find steel given as .283 pounds per cubic inch—then in this case $c = .283$. Then $2 \times 2 \times .7854 \times 10 \times 12 \times .283 = 106.68$ pounds as weight of shaft. Transposing once more we find that as $d^2 \times .7854 \times l = \text{cubical contents } (a)$, then

$$d = \sqrt{\frac{a}{.7854 \times l}}$$

or square root of

$$\frac{376.99}{.7854 \times 120}$$

376.99 being the cubical contents of the shaft in question.

This must now be solved, and the square root of this result equals d . In the same way we transpose for l , when

$$l = \frac{a}{d^2 \times .7854}$$

If a shaft must have a certain weight, first divide this by the weight per cubic inch, which will give the required cubical contents, and the result can easily be found by the formulas given. Of course we can transpose the whole formula, including weight, but it would only add to the number of formulas without being necessary.

Before going on with useful shop formula, let us take a "horrible example" and see how it is solved, which will perhaps clear up some of the mysteries better than the simple formulas. Taking

$$A = \frac{b}{2} \sqrt{a^2 - \left[\frac{a^2 + b^2 - c^2}{2b} \right]^2}$$

where $a=3$, $b=5$, $c=4$. The fraction being enclosed in the brackets, indicates that it is to be considered as *one* quantity, and after being squared, subtracted from a^2 , and the square root of this difference multiplied by

$$\frac{b}{2}; \text{ or } \sqrt{9 - \left[\frac{9+25-16}{2 \times 5} \right]^2}$$

Taking the fraction, $\left(\frac{9+25-16}{2 \times 5} \right)^2$, we have $\frac{34-16}{2 \times 5} = \frac{18}{10} = 1.8$. Then squaring 1.8 we have 3.24. Subtracting this from 9, gives 5.76, and square root of this is 2.4 which multiplied by

$$\frac{b}{2}, \text{ which is } \frac{5}{2}, \text{ gives } 2.4 \times \frac{5}{2} = 6 = A.$$

If the brackets included all the figures under the vinculum (bar from the square root sign) the calculations would be

$$\sqrt{9 - \left(\frac{9+25-16}{2 \times 5} \right)^2}$$

$(9-1.8)^2 = \sqrt{7.2^2} = 7.2 = A$, so that special care must be taken to follow the signs correctly. These particular points will be shown as we proceed.

Taking the formula for the area of a ring where $A = .7854 (D^2 - d^2)$

D =outer diameter.

d =inner diameter.

A =area in square measure of whatever unit the diameters are given in, if D and d are inches, A will be square inches, etc.

$D=10$ inches, $d=6$ inches. Then $A = .7854 \times (D^2 - d^2)$. The brackets denote

that this part must be solved first. $10 \times 10 = 100$, $6 \times 6 = 36$, $100 - 36 = 64$. $A = .7854 \times 64 = 50.26$ square inches. By adding l =length; to the formula we can find the cubical contents and weight of any hollow cylinder or pipe, and calling this one 12 inches long we have $50.26 \times 12 = 602.6$ cubic inches, from which weight can be found for any material.

As an example of working backwards, find the thickness of a cast iron cylinder whose outer diameter is 10 inches, length 15 inches, and which must weigh 200 pounds. Cast iron is given as .26 pound per cubic inch. So dividing 200 by .26 we find that $(200 \div .26 = 769.23)$ 769.23 cubic inches are necessary to make the required weight. Dividing this by the length, 15 inches, we have 51.28 square inches as the area of the ring whose outer diameter is 10 inches. Then we can say $51.28 (A) = .7854 \times (100 - d^2)$ and transposing we have

$$d = \sqrt{D^2 - \frac{A}{.7854}} = \sqrt{100 - \frac{51.28}{.7854}} = \sqrt{34.71} = 5.89$$

inches internal diameter.

Chapter V.

Mensuration.

This can be called the measuring or computing of surfaces, areas and volumes of bodies, and is very useful to the mechanic in many ways. Taking a triangle first, figure 1, as this has the least number of sides of any figure; we discover that all the sides and angles are equal, hence it is called an equilateral triangle. Either half of it, as laid out by the dotted vertical dividing line, is called a right angled triangle because it contains one right angle.

A right angle is one formed by two lines perpendicular to each other or with an opening of 90 degrees or one-quarter the number of degrees of a complete circle.

This can be more readily seen in figure 2, if we take O as a center, and note that the four angles G O E, E O H, H O F, and F O G are all equal, and all are right angles.

The base of a triangle or other figure can be defined as the side on which it rests, in the case of figure 1, the base of the equilateral triangle A B C is the line B C, and half the base will of course be C D or D B.

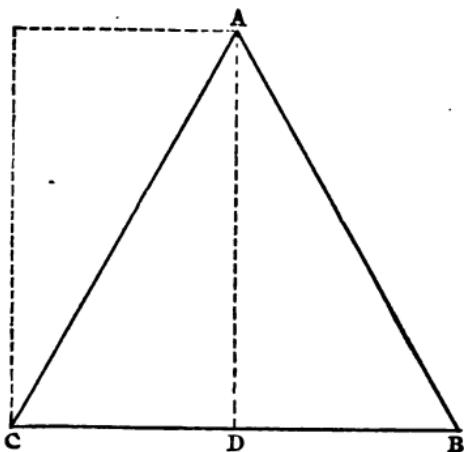


FIG. 1.

The vertical height is shown by the line A D, and can be defined as a line perpendicular to the base and connecting it to the point or apex.

It is plain that if we took the right hand side and placed it on the upper left hand, as shown by the dotted lines, we have made a rectangle and that the area

will be the height multiplied by the base C D. But as we only have the dimensions of the sides of the triangles and not the vertical height, we must find this before we can find the area.

In a right angled triangle the square of the hypothenuse or slanting side, equals

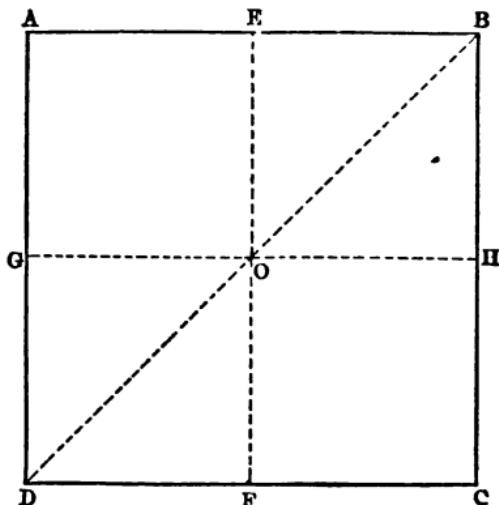


FIG. 2.

the square root of the base plus the square of the vertical height, or calling the vertical height a , the base b and the hypothenuse c we say $c^2 = a^2 + b^2$ or $c = \sqrt{a^2 + b^2}$. But as we know c to be 2 inches and the base b 1 inch (one half of c) we must find

a, Transposing the formula we have
 $a^2 = c^2 - b^2$ or $a = \sqrt{c^2 - b^2}$ and $b^2 = c^2 - a^2$
or $b = \sqrt{c^2 - a^2}$.

Then $a = \sqrt{4 - 1} = 1.733$ inches.

The area then equals $1.733 \times 1 = 1.733$ square inches.

The usual rule is to multiply the height by the base and divide by two, and as the base of the whole triangle is 2 inches we say $\frac{1.733 \times 2}{2} = 1.733$; a little reasoning shows this.

Taking the square we have a simple form to find the area, simply multiplying one side by the other, or squaring.

The diagonal or hypotenuse is found in the same way as with the triangle although it is often more convenient to multiply the square of one side by 2 than to add both together, and of course it brings the same result.

For example, having a 3-inch square to find the diagonal.

$c^2 = b^2 + a^2$ or $c = \sqrt{b^2 + a^2}$ or $c = \sqrt{2b^2}$.
 $c = \sqrt{9 + 9}$ or $c = \sqrt{2 \times 9} = \sqrt{18} = 4.24$ inches as diagonal.

We can work this backward and

solve a practical problem at the same time. We want a square reamer to ream a hole 3 inches in diameter; what will be the dimension of the flat sides? The diagonal is what reams the holes and this must be 3 inches, so we have $c = \sqrt{a^2 + b^2}$. and $c = 3$ inches.

To find a we have $a = \sqrt{c^2 - b^2}$ or knowing that a and b are the same and that $c^2 = a^2 + b^2$ we can say $a^2 + b^2 = c^2$ or $a^2 = \frac{1}{2}c^2$ or $a = \sqrt{\frac{1}{2}c^2}$.

As $c = 3$, $c^2 = 9$, and $\frac{1}{2}$ of 9 = 4.5, then the square root of 4.5 = 2.121 inches which gives the side of reamer.

Calling the square in figure 2 one inch each way, we know that its area must be one square inch. Dividing this into quarters as shown, will aid in dispelling a little fog which too often arises in the matter and which leads some to claim that because a square whose sides are one inch contains one square inch, a square whose sides are $\frac{1}{2}$ inch contains $\frac{1}{2}$ a square inch.

A glance at the figure shows this area to be $\frac{1}{4}$ of a square inch and figures back

it up by saying $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ or $.5 \times .5 = .25$.

A rectangle is subject to the same laws as a square and triangle, the area and diagonal being found as with square.

The rules for circles were given under the chapter on "formula" and need not be

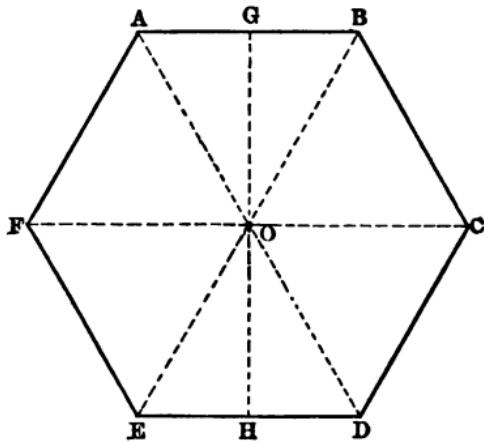


FIG. 3.

repeated, although a few examples will be given later.

The square is also a rectangular figure, that is all its angles are right angles; its sides are also equal. The figure A B H G in figure 2 is also a rectangle although not a square.

Figure 3 is a hexagon (meaning six sided figure), and the area can be found

by dividing it into six triangles as A O B, B O C, C O D, etc., and after finding the area of one triangle, the whole area can

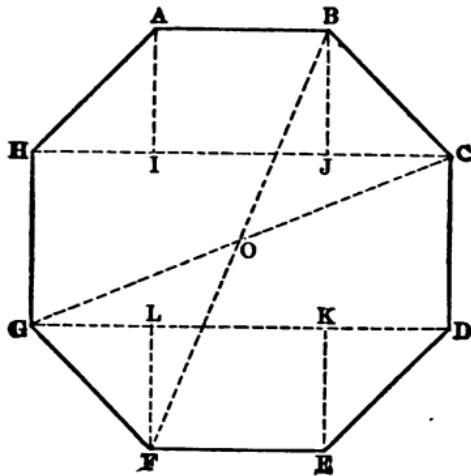


FIG. 4.

be easily calculated. A handy table has been worked out as follows.

Area of Regular Figures.

Number of sides.	Constant.	Number of sides.	Constant.
3	.433013	8	4.828427
4	1.—	9	6.181824
5	1.720477	10	7.694209
6	2.598076	11	9.365640
7	3.633912	12	11.196152

To use this table, square (multiply by itself) the length of one side and multiply by the constant.

Taking the octagon in figure 4 we can either calculate its area by dividing it into the numerous parts shown; into triangles as B O C, F O G, etc., or into rectangles as H C D G, A B J I, and L K E F, with the four triangles H I A, B J C, etc., and it is best to know how to do this as the table may be mislaid. But taking the table and calling one side, as B C, 2 inches, we square this (2×2), and have $4 \times 4.828427 = 19.318708$, as the area of the octagon. The area of any other regular figure (having sides and angles equal) up to one with twelve sides, can be found by using the table as shown, still it is well to know how to work them out without the table.

The formula for the area of a ring was given in chapter 4, but in figure 5 we have a case which might readily puzzle one at first glance.

Call the outer diameter of the shaft 10 inches and the hole which is eccentric to the shaft, 5 inches in diameter; what is the area of the one sided ring?

Of course the area is exactly the same

as though the hole was in the centre of the shaft, and we use the formula:

$$\text{Area} = .7854 (D^2 - d^2) \text{ as before.}$$

A little study will set these problems straight.

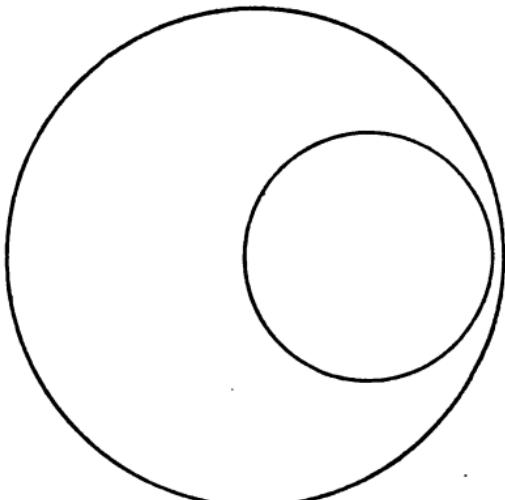


FIG. 5.

Another problem in calculating weight will give a very good illustration.

What will be the weight of a turret as shown in figure 6, with an outside diameter of 20 inches, depth of 6 inches, center hole for stud 3 inches, and having 6 holes for tools, each 2 inches in diameter. First

calculate for volume as though it was solid.

$$D^2 \times .7854 = \text{area of top (or bottom).}$$

$$\text{Area} \times \text{depth} = \text{cubical contents.}$$

$$20 \times 20 \times .7854 = 314.16 \text{ sq. inches.}$$

$$314.16 \times 6 = 1884.96 \text{ cubic inches.}$$

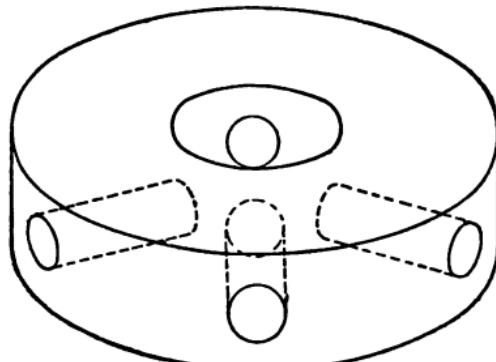


FIG. 6.

Now deducting the various holes. Central hole of 3 inches diameter by 6 inches long. $3 \times 3 \times .7854 = 7.0686$ and $7.0686 \times 6 = 42.4116$ or $42.41 + \text{cubic}$ inches.

Taking holes next, we find that as the turret is 20 inches in diameter and central hole 3 inches, the amount of solid metal in line with the diameter must be $20 - 3 = 17$ inches; or each hole must be $8\frac{1}{2}$

inches long as $8\frac{1}{2} + 3 + 8\frac{1}{2} = 20$ inches, the diameter of turret.

A hole 2 inches in diameter by $8\frac{1}{2}$ inches long gives $2 \times 2 \times .7854 = 3.1416 \times 8.5 = 26.70$ cubic inches each. Six holes will give $6 \times 26.70 = 160.20$ cubic inches for the six holes. Collecting the different volumes to be deducted, we have 42.41 cubic inches for central hole, plus 160.20 cubic inches for the six tool holes gives $42.41 + 160.20 = 202.61$ cubic inches to be deducted from 1884.96 cubic inches. $1884.96 - 202.61 = 1682.35$ cubic inches, the total volume of turret.

Taking cast iron at .26 pounds per cubic inch we have $1682.35 \times .26 = 437.51$ pounds. This is not absolutely correct owing to the slight difference between the curvature of the outer diameter of turret and the central hole, but the difference is so small as to be of little consequence.

The ball or sphere is not often met with in practice, but it is well to know how to calculate its surface and contents.

The surface of a sphere is found by multiplying the area of a circle of the same diameter by 4.

A 10 inch sphere or ball will have a surface equal to four times the area of a circle of the same diameter, or in formula language: $D^2 \times .7854 \times 4$ or $(D^2 \times 3.1416) \times 4$ =surface of sphere. $10 \times 10 \times .7854 = 78.54 \times 4 = 314.16$ square inches, as surface of a 10 inch ball.

The cubical contents or volume of a sphere is found by multiplying the surface by $\frac{1}{3}$ the radius or by $\frac{1}{6}$ the diameter.

In our 10 inch sphere we have 314.16 square inches multiplied by $\frac{1}{6}$ of 10 or $1\frac{2}{3} = 523.6$ cubic inches.

Another and perhaps easier rule is to multiply the cube of the diameter by $\frac{1}{6}$ "pi" (or .5236, as $3.1416 \div 6 = .5236$).

This gives diameter cubed or $10 \times 10 \times 10 = 1,000 \times .5236 = 523.6$ cubic inches as before.

The cone is another form which it is sometimes handy to know about, as for example the lathe center you use in everyday work. You can easily calculate the surface and weight of all except the point, but how shall we find that except by guessing at it? The wise men of old solved

that as they did much else that we use without thanking them.

The curved (convex in this case) surface of a cone equals the circumference of the base multiplied by half the slant height or side.

Take a lathe center one inch in diameter at the base and if it is ground to 60 degrees the slant side will also be one inch. Then $1 \times 3.1416 = 3.1416 \times \frac{1}{2} (\frac{1}{2} \text{ of } 1) = 1.5708$ square inches surface.

The volume or cubical contents equals the area of the base multiplied by $\frac{1}{3}$ the *vertical height*, not the *slant height*.

Here we must use our triangle formula to find the height, and we have the hypotenuse as 1 inch, the base as $\frac{1}{2}$ inch, so we say $1 \times 1 - .5 \times .5 = 1 - .25 = .75$.

Square root of $.75 = .866$.

Then the area of base equals

$1 \times 1 \times .7854 = .7854$; $.7854 \times \frac{1}{3}$ of $.866 = .7854 \times .288 = .2261$ of a cubic inch.

Take a block of steel like figure 7, and estimate its weight, the dimensions being as given in the figure.

This is simply a case of careful calculation and it can best be done dividing it into sections as shown by the dotted lines and computing each section, separately,

noting and adding each section and not forgetting to deduct the half-round groove

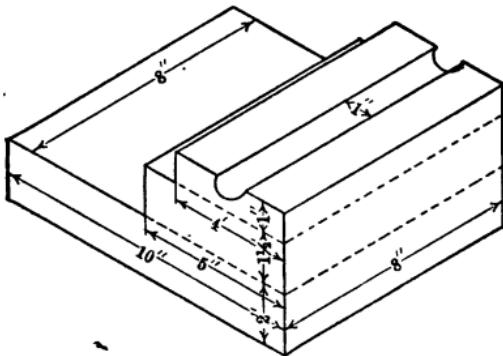


FIG. 7.

on top of the block. The bottom block will be $10 \times 8 \times 2 = 160$ cubic inches.
the next $5 \times 8 \times 1\frac{1}{2} = 60$ " "
the top $4 \times 8 \times 1 = 32$ " "

Total (not deducting groove), 252 " "

A one inch circle is $1 \times 1 \times .7854 = .7854$ square inches $\times 8 = 6.2832$ cubic inches, and as the groove is half round we divide this by 2 making 3.1416 to deduct from 252 = 248.8584 cubic inches.

A cubic inch of steel weighs .283 pounds and $248.85 \times .283 = 70.424$ pounds.

The following table of metals giving the weights per cubic inch may be useful in calculations of this kind.

PROPERTIES OF METALS.
FROM DIFFERENT SOURCES.

	Melting Point. Degrees Fahr- enheit.	Weight in lbs. per cubic foot.	Weight in lbs. per cubic inch.	Tensile Strength in lbs. per square inch.
Aluminum.....	1140	166.5	.0963	15,000-30,000
Antimony.....	810-1000	421.6	.2439	1,050
Brass (average)...	1500-1700	523.2	.3027	30,000-45,000
Copper.....	1930	552.	.3195	30,000-40,000
Gold (pure).....	2100	1200.9	.6949	20,380
Iron, cast.....	1900-2200	450.	.2604	20,000-35,000
“ wrought....	2700-2830	480.	.2779	35,000-60,000
Lead.....	618	709.7	.4106	1,000-3,000
Mercury.....	-39	846.8	.4900	...
Nickel.....	3000	548.7	.3175	...
Silver.....	1800	655.1	.3791	40,000
Steel.....	2370-2685	489.6	.2834	50,000-120,000
Tin.....	475	458.3	.2652	5,000
Zinc.....	780	436.5	.2526	3,500

NOTE.—The wide variations in tensile strength are due to the different forms and qualities of the metal tested. In the case of lead, the lowest strength is for lead cast in a mold, the highest for wire drawn after numerous workings of the metal. With steel it varies with the proportion used in mixing, which is varied according to the grade required. Mercury becomes liquid at 89 degrees below zero.

Chapter VI.

Rules for Selecting Change Gears for Screw Cutting.

(For explanation of principle on which these rules are founded, see Chapter XVII., page 98.)

First look over the lathe and see how it is made; see if the change gears go directly on the spindle and the leading screw. If not, ascertain how many revolutions the stud which takes the first change gear makes, to one revolution of the spindle, or how many revolutions the stud that takes the last change gear makes to one revolution of the leading screw, or both.

Multiply the number of threads per inch in the leading screw by the number or numbers found, as above, and *assume* the result to be the number of threads per inch in the leading screw.

Examples: Number of revolutions of spindle to one revolution of stud that takes the first change gear=2. Number

of threads per inch in leading screw=4. Then $4 \times 2 = 8$, the *assumed* number of threads per inch in the leading screw, or

Number of revolutions of stud that takes the last change gear, to one revolution of leading screw=2. Number of threads per inch in leading screw=4. Then $4 \times 2 = 8$, the *assumed* number of threads per inch in the leading screw, or

Number of revolutions of spindle to one revolution of stud that takes the first change gear=2, *and* number of revolutions of stud that takes the last change gear to one revolution of leading screw =2. Then $4 \times 2 \times 2 = 16$, the *assumed* number of threads per inch in leading screw.

Then take the number of threads per inch desired to be cut, and the *assumed* number of threads per inch of the leading screw, and divide the larger by the smaller to get the *ratio*.

This ratio must exist between the gears to be used, therefore:

Select any gear and multiply the number of teeth by this ratio to find the

number of teeth in the other gear. The ratio will usually come in the form of a mixed number.

Example: Assumed number of threads per inch in leading screw = 16.

Number of threads per inch desired to be cut = 14. Then ratio = $1\frac{2}{4} = 1\frac{1}{2}$. [Reduce all fractions to lowest terms.]

In order to select two gears, one of which has $1\frac{1}{2}$ times as many teeth as the other, it is evident that the other gear *must* have some number of teeth that can be divided by 7.

Therefore, if there is no change gear with the lathe, with a number of teeth which can be divided by 7, *the number of threads per inch desired cannot be cut on that lathe.*

When it is known that the number of threads can be cut on the lathe, it is usually easier to proceed thus:

Ascertain the number by which the teeth of the change gears increase, and multiply the assumed number of threads in leading screw and the number of threads desired to be cut, both by this number.

Example: Number by which teeth of change gears increase=4.

Assumed number of threads in leading screw=8.

Number of threads desired to be cut =7.

Then

$$\begin{array}{l} 4 \times 7 = 28 \\ 4 \times 8 = 32 \end{array} \} \text{ the two gears required.}$$

If these two gears are not in the set, multiply both by any number that will give gears that are in the set.

When the thread desired to be cut is coarser than the *assumed* number of threads of leading screw, put the *larger* gear on the spindle (or stud connected with the spindle) and when the thread desired to be cut is finer than the *assumed* number of threads of leading screw, put the *smaller* gear on the spindle.

When *fractional* threads are desired to be cut, multiply *both* the fractional number and the assumed number of threads of leading screw, by some number that will raise the fractional number to a *whole* number. Example:

Number of threads desired to be cut
 $= 5\frac{3}{4}$.

Assumed number of threads of leading screw=8. Then $5\frac{3}{4} \times 4 = 23$; $8 \times 4 = 32$ and $32 \div 23 = 1\frac{9}{23}$, the ratio required, or, if there are change gears of 23 and 32 teeth with the lathe, there is no occasion for further figuring.

Practical hint: *Measure* the thread being cut to be sure no error has been made in calculating the gears.

NOTE.

A thorough understanding of Chapter XVII. is all that is necessary to enable the student to easily calculate *compound* gearing.

Chapter VII.

Depth of V Threads.

It is easy to find the depth of a thread from a catalogue or other book of reference, but it is best to know the "why" of things as we go along.

A V thread is an equilateral triangle (as the angles are all 60 degrees and the sides of the same length), and the two sides and the distance between threads will be the same.

Referring to figure 1, we have a triangle whose sides are 1 inch, and, of course, representing a 1 inch pitch of thread. To find the depth of the thread we must find the height of the triangle, and we know how to do this from the chapter on mensuration, which says: "The square of the hypotenuse minus the square of the base equals the square of the height."

The base is of course just one-half the distance between threads or $\frac{1}{2}$ inch, so we have $1 \times 1 = 1$ minus $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4} = 1 - \frac{1}{4}$

$= \frac{3}{4}$ which equals the square of the height.

Then the square root of $\frac{3}{4}$ (or .75) equals the height and the square root of .75 = .866 + as the depth of this thread of 1 inch pitch.

It is evident that if we wish to count the depth of the thread on *both sides* of the bolt or tap we must double this and use 1.733 which is the double depth.

Now, if we have a thread which is 4 to the inch, we can find its single depth by dividing .866 + by 4 which gives .2165, or dividing 1.733 by 4 gives .433 for the double depth; the same as multiplying the first by 2.

It is easier to remember that a one inch thread is .866 of an inch for single depth or 1.733 for double depth (counting both sides), and it brings us to a very handy formula used in Chapter VIII. made from this data, which is easily remembered and which will be useful to the machinist and tool maker.

Chapter VIII.

Drilling for Taps.

It frequently happens that when we want a tapped hole in a piece of work, the table of tap drills that we have saved is somewhere else, so we usually guess at the size.

But there is a very handy little formula which can be easily remembered and worked out with a piece of chalk when occasion requires.

For V threads it is:

$$S = T - \frac{1.733}{N} \text{ in which}$$

S =size of drill

T =outside diameter of tap

N =number threads per inch.

A .75 inch tap with 10 threads will then require: $S = .75 - \frac{1.733}{10} = .75 - .1733 = .5767$, or practically .58, although a $\frac{5}{8}$ inch drill will generally be used as it

allows a little, .02 on a side, for being forced up by the tap.

In cast iron it is better not to allow a perfectly full thread as the sharp edge crumbles and is apt to spoil the thread when unscrewed, so an allowance of .02 or .03 on a side for fairly coarse threads, over 10 to the inch, is good practice.

For United States Standard threads, which are only $\frac{3}{4}$ the depth of a V thread, the formula has a different constant, being

1 3 instead of 1.733 and reads $S = T - \frac{1.3}{N}$.

Taking the same case as before we have $S = .75 - \frac{1.3}{10} = .75 - .13 = .62$ or $\frac{5}{8}$ inch without any allowance, but as the U. S. S. thread has a flat top and bottom, this is not necessary, even for cast iron, and no allowance need be counted on.

In fact we might use the U. S. S. formula in nearly any case, as in the V thread it allows for crumbling of cast iron and the forcing up of wrought iron.

Judgment, gained from experience, will tell you how much to allow, if any.

But suppose you are a tool maker and have a die to make, which is to cut an 18 V thread, 2.25 inches in diameter.

$$\text{Then } S = 2.25 - \frac{1.733}{18} = 2.25 - .09 =$$

2.16 inches, which is the correct size to bore the die to allow a full thread.

For the U. S. S. thread the application is the same, using 1.3 instead of 1.733, and this will be found very handy by any tool maker.

TAP DRILLS.

Tap.	Threads per inch.	Drill for V thread.	Drill for U. S. S. thread.
$\frac{1}{4}$	20	$\frac{11}{16}$	$\frac{3}{8}$
$\frac{5}{16}$	18	$\frac{15}{16}$	$\frac{1}{4}$
$\frac{9}{32}$	16	$\frac{6}{4}$	$\frac{1}{8}$
$\frac{7}{16}$	14	$\frac{9}{8}$	$\frac{6}{4}$
$\frac{13}{32}$	13	$\frac{5}{4}$	$\frac{1}{3}$
$\frac{9}{16}$	12	$\frac{8}{6}$	$\frac{3}{8}$
$\frac{5}{8}$	11	$\frac{7}{6}$	$\frac{6}{4}$
$\frac{3}{4}$	10	$\frac{5}{4}$	$\frac{5}{8}$
$\frac{7}{8}$	9	$\frac{4}{3}$	$\frac{3}{6}$
1	8	$\frac{3}{2}$	$\frac{7}{8}$
$1\frac{1}{8}$	7	$\frac{2}{1}$	$\frac{1}{6}$
$1\frac{1}{4}$	7	$1\frac{1}{32}$	$1\frac{1}{16}$
$1\frac{5}{8}$	6	$1\frac{1}{16}$	$1\frac{5}{32}$
$1\frac{1}{2}$	6	$1\frac{1}{8}$	$1\frac{9}{16}$
$1\frac{5}{8}$	$5\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{5}{8}$
$1\frac{1}{4}$	5	$1\frac{1}{2}$	$1\frac{1}{2}$
$1\frac{1}{8}$	5	$1\frac{1}{8}$	$1\frac{1}{8}$
2	$4\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$

Chapter IX.

Bolts and Nuts.

The thickness of a bolt head and nut is practically the same as the diameter of the bolt for rough bolts—for the finished bolts it is $\frac{1}{8}$ of an inch less.

Diameter of rough bolt heads equal one and one-half times diameter of bolt, plus $\frac{1}{8}$ of an inch.

Or calling diameter = D we have:

Diameter of rough bolt head = $1\frac{1}{2}D + \frac{1}{8}$.

Thickness of head of ordinary nut = D .

Of check or lock nuts = $\frac{1}{2}D$.

Having the diameter "across the flats" given (the usual way and the diameters as meant above) it is sometimes handy to know the diameter across the corners.

Multiply the diameter as given above by 1.414 for a square nut and by 1.156 for a hexagon nut and you have the diagonal or long diameter (or distance across

corners). And having this diameter given, the regular or "flat" diameter can be found by dividing by numbers 1.414 and 1.156 as given above.

BOLT TABLE—U. S. S. THREAD.

Diam.	Threads to inch.	Diam. at bottom of thread.	Area of bolt.	Area at bottom of thread.	Stress at 10000 lbs. per square inch.	Shearing strength at 10000 lbs. full bolt.
$\frac{1}{4}$ in	20	.1850	.0491	.0269	269	491
$\frac{5}{16}$ "	18	.2403	.0767	.0454	454	767
$\frac{3}{8}$ "	16	.2938	.1104	.0678	678	1104
$\frac{7}{16}$ "	14	.3447	.1503	.0933	933	1503
$\frac{1}{2}$ "	13	.4001	.1963	.1257	1257	1963
$\frac{9}{16}$ "	12	.4542	.2485	.1621	1621	2485
$\frac{5}{8}$ "	11	.5069	.3068	.2018	2018	3068
$\frac{3}{4}$ "	10	.6201	.4418	.3020	3020	4418
$\frac{7}{8}$ "	9	.7307	.6013	.4193	4193	6013
1 "	8	.8376	.7854	.5510	5510	7854
$1\frac{1}{8}$ "	7	.9394	.9940	.6931	6931	9940
$1\frac{1}{4}$ "	7	1.0644	1.2272	.8899	8899	12272
$1\frac{5}{8}$ "	6	1.1585	1.4849	1.0541	10541	14849
$1\frac{1}{2}$ "	6	1.2835	1.7671	1.2938	12938	17671
$1\frac{5}{8}$ "	$5\frac{1}{2}$	1.3888	2.0739	1.5149	15149	20739
$1\frac{1}{4}$ "	5	1.4902	2.4053	1.7441	17441	24053
2 "	$4\frac{1}{2}$	1.7113	3.1416	2.3001	23001	31416
$2\frac{1}{4}$ "	$4\frac{1}{2}$	1.9613	3.9761	3.0213	30213	39761
$2\frac{1}{2}$ "	4	2.1752	4.9087	3.7163	37163	49087
$2\frac{3}{4}$ "	4	2.4252	5.9396	4.6196	46196	59396
3 "	$3\frac{1}{2}$	2.6288	7.0686	5.4277	54277	70686

NOTE.—Shearing strain at bottom of thread at 10000 lbs. will be same as "stress" at same tension.

Chapter X.

Speed of Pulleys and Gears.

In making calculations concerning speeds for driving machinery there is no rule so much used as proportion.

If one man can lift 200 pounds, two men can lift 400 pounds, so we say, as 1 man is to 2 men so is one man's work (200 pounds) to two men's work (400 pounds). We write this $1:2::200:400$ the signs reading as *1 is to 2, so is 100 to 400*. Now if we say that 2 men can lift 400 pounds and we wish to find what 1 man can lift we say $2:1::400:200$. Take another case:

A 36-inch pulley is running 200 revolutions per minute and driving a 12-inch pulley—how fast is this running? Now by a little reasoning we know the small pulley is running faster than the larger one which is driving, so we say as $12:36::200:\text{the answer}$. The rule for solving these problems is multiply the *means* (the second and third terms) together and divide by one of the *extremes*, to find the

other—the extremes being the outside figures or the first and fourth terms as they are called. To make these more clear we may see that the first and fourth terms multiplied together gives the same result as multiplying the second and third terms or $1\text{st} \times 4\text{th} = 2\text{nd} \times 3\text{rd}$ or "means" = "extremes." Taking the problem in hand and we have $12:36::200:?$ We have 1st, 2nd and 3rd terms and multiplying 2nd and 3rd terms we have $36 \times 200 = 7200$. The fourth must equal that number which, multiplied by the first, will also equal 7200 or $7200 \div 12 = 600$. We can shorten this a little in this case by noting that $36 = 3 \times 12$ and saying $1:3::200:600$ or simply multiply 200 by 3.

A 12-inch pulley runs 250 revolutions per minute and is to drive a machine at 150 revolutions, what size pulley must be on the machine? The *driven* pulley must run *slower* than the driver, hence must be *larger*, so knowing the answer must be larger, we say, as $150:250::12:\text{answer}$. $250 \times 12 = 3000 \div 150 = 20$ inches. It will be noted that the first and second terms are of the same *kind* of things, revolutions in

this case, and that the third and fourth terms are also similar, so knowing what the answer must be, whether inches, revolutions or dollars, you know which to make the third term.

If it takes 67 pounds of metal to make 13 castings how much will it take to make 8 castings? The question is how many pounds, then 67 pounds is the third term. If 67 pounds makes 13 castings, it will evidently take less to make 8 castings, so put the less number for the second term and have as $13:8::67:\text{answer}=41.2$ pounds.

A grinder must run 1600 revolutions and has a 6-inch pulley, the line shaft runs 200 revolutions, what size pulley must go on the line shaft? As answer must be the size of pulley, make 6 inches the third term. Grinder must run faster than line shaft, so driving pulley must be larger than pulley on grinder so make larger number the second term. Then as $200:1600::6:48$ or as $1:8::6:48$, so that pulley on shaft must be 48 inches.

In figuring for pulleys or gears remember that when the:

Driving pulley is *larger* than driven
it runs *slower* than the driven.

Driving pulley is *smaller* than driven
it runs *faster* than the driven.

Driven pulley is *larger* than driving
it runs *slower* than driving.

Driven pulley is *smaller* than driving
it runs faster than driving. And that
when the desired revolutions of the:

Driven are *less* than those of the
driver, the driven pulley must be the
larger.

Driven are *more* than those of the
driver, the driven must be the *smaller*.

Reason these out and then prove
them by calculation.

Gears which *run together* can be taken
the same as pulleys, either by calculating
from the number of teeth or the pitch
diameter.

Proportion is a labor saver, and only
takes a little reasoning to be thoroughly
understood. Compound proportion need
hardly be considered here as it might
cause confusion. You can work out all
you are likely to need with the simple
proportion given.

Chapter XI.

Calculating Speed of Milling Cutters— Drills—or Work.

Call d =diameter of rotating piece in inches.

S =surface speed in feet per minute.

n =revolutions per minute.

Then $S = \frac{\pi \times d \times n}{12}$ or $.2618 \times d \times n$;

$$n = \frac{S}{.2618d}, \quad d = \frac{3.82 \times S}{n}$$

For example take a piece of work or milling cutter 4 inches in diameter, running 100 revolutions per minute.

Then $S = \frac{3.1416 \times 4 \times 100}{12}$ or $.2618 \times 4 \times 100$
 $= 104.72$ feet per minute.

Taking another case, we want a 10-inch emery wheel to run 5,000 feet per minute; how many revolutions per minute shall it run?

$$n = \frac{S}{.2618 \times d} = \frac{5000}{.2618 \times 10} = 1909 +$$

Approximate revolutions may be found by multiplying speed in feet per minute by 4 and dividing by the diameter in inches.

By this method we have $5,000 \times 4 \div 10 = 2,000$ revolutions, which is not bad for quick estimating.

If we wish a milling cutter to run 200 feet per minute and the machine can only make 70 revolutions, what diameter must the mill be.

Then $d = \frac{3.82 \times 200}{70} = 10.91$ inches in diameter.

The constant 3.82 is obtained by dividing 12 (inches to the foot) by 3.1416, so the result is the same as: Speed in feet per minute multiplied by 12 (to reduce to inches) and this divided by 3.1416 and the revolutions per minute, so we see there is nothing mysterious about these constants.

A handy table to consult is given by Messrs. Beaman & Smith, of Providence, R. I., as follows:

TABLE OF CUTTING SPEEDS.

Feet Minute	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'
Diam.	REVOLUTIONS PER MINUTE.									
1/2	38.2	76.4	114.6	152.9	191.1	229.3	267.5	305.7	344.0	382.2
5/8	30.6	61.2	91.8	122.5	153.1	183.7	214.3	244.9	275.5	306.1
3/4	25.4	50.8	76.3	101.7	127.1	152.5	178.0	203.4	228.8	254.2
7/8	21.8	43.6	65.5	87.3	109.1	130.9	152.7	174.5	196.3	218.9
1	19.1	38.2	57.3	76.4	95.5	114.6	133.8	152.9	172.0	191.1
1 1/8	17.0	34.0	51.0	68.0	85.0	102.0	119.0	136.0	153.0	170.0
1 1/4	15.3	30.6	45.8	61.2	76.3	91.8	106.9	122.5	137.4	153.1
1 3/8	13.9	27.8	41.7	55.6	69.5	83.3	97.2	111.1	125.0	138.9
1 5/8	12.7	25.4	38.2	50.8	63.7	76.3	89.2	101.7	114.6	127.1
1 3/4	11.8	23.5	35.0	47.0	58.8	70.5	82.2	93.9	105.7	117.4
2	10.9	21.8	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109.1
2 1/8	10.2	20.4	30.6	40.7	50.9	61.1	71.3	81.5	91.9	101.9
2 1/4	9.6	19.1	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5
2 5/8	8.5	17.0	25.4	34.0	42.4	51.0	59.4	68.0	76.2	85.0
2 3/4	7.6	15.3	22.9	30.6	38.2	45.8	53.5	61.2	68.8	76.3
3	6.9	13.9	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.5
3 1/8	6.4	12.7	19.1	25.5	31.8	38.2	44.6	51.0	57.3	63.7
3 1/4	5.5	10.9	16.4	21.8	27.3	32.7	38.2	43.6	49.1	54.5
4	4.8	9.6	14.3	19.1	23.9	28.7	33.4	38.2	43.0	47.8
4 1/8	4.2	8.5	12.7	16.9	21.2	25.4	29.6	34.0	38.1	42.4
4 1/4	3.8	7.6	11.5	15.3	19.1	22.9	26.7	30.6	34.4	38.2
5	3.5	6.9	10.4	13.9	17.4	20.8	24.3	27.8	31.3	34.7
5 1/8	3.2	6.4	9.6	12.7	15.9	19.1	22.3	25.5	28.7	31.8
6	2.7	5.5	8.1	10.9	13.6	16.4	19.1	21.8	24.6	27.3
7	2.4	4.8	7.2	9.6	11.9	14.3	16.7	19.1	21.1	23.9
8	2.1	4.2	6.4	8.5	10.6	12.7	14.9	17.0	19.1	21.2
9	1.9	3.8	5.7	7.6	9.6	11.5	13.4	15.3	17.2	19.1
10	1.7	3.5	5.2	6.9	8.7	10.4	12.2	13.9	15.6	17.4
11	1.6	3.2	4.8	6.4	8.0	9.6	11.1	12.7	14.3	15.9
12	1.5	2.9	4.4	5.9	7.3	8.8	10.3	11.8	13.2	14.7
13	1.4	2.7	4.1	5.5	6.8	8.1	9.6	10.9	12.3	13.6
14	1.3	2.5	3.8	5.1	6.4	7.6	8.9	10.2	11.5	12.7
15	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.7	11.9
16	1.1	2.2	3.4	4.5	5.6	6.7	7.9	9.0	10.1	11.2
17	1.1	2.1	3.2	4.2	5.3	6.4	7.4	8.5	9.6	10.6
18	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.1	10.1
19	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.6	8.6	9.6
20	.9	1.8	2.7	3.6	4.5	5.5	6.4	7.3	8.1	9.1
21	.9	1.7	2.6	3.5	4.3	5.2	6.1	6.9	7.8	8.7
22	.8	1.7	2.5	3.3	4.1	5.0	5.8	6.6	7.5	8.3
23	.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0
24	.8	1.5	2.3	3.1	3.8	4.6	5.3	6.1	6.9	7.6
25	.7	1.5	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3
26	.7	1.4	2.1	2.8	3.5	4.2	5.0	5.7	6.4	7.1
27	.7	1.4	2.0	2.7	3.4	4.1	4.8	5.5	6.1	6.8
28	.7	1.3	2.0	2.6	3.3	4.0	4.6	5.3	5.9	6.6
29	.6	1.3	1.9	2.5	3.2	3.8	4.5	5.1	5.7	6.4
30										

Chapter XII.

Speeds of Drills and Taps.

It will be seen later that the tapping speed varies from $\frac{1}{2}$ to $\frac{1}{3}$ of the drilling speed, which will be a good thing to remember when tapping by power. And we wish to caution the reader that these figures, the same as much other data, are especially valuable as a *guide* only, not to be followed absolutely, as the hardness of all the metals vary, and while the figures are probably correct as an average, judgment and the manner in which the drill and the tap stands the work should determine the speed to be used.

If you try the speed given in the table and keep as near it as you can, you will not be far wrong.

While some consider that the speed should vary directly with the diameter and a 2 inch drill run half as fast as a 1 inch drill, modern practice follows more the speeds shown in table. The same can be done for tapping speeds.

As to drill feeds, the Morse Twist Drill and Machine Co. advises 160 revolutions per inch of depth for sizes from $\frac{1}{16}$ to $\frac{1}{4}$ inch diameter; 120 to 140 for $\frac{3}{8}$ to $\frac{1}{2}$ inch diameter; for $\frac{3}{4}$ inch 100 revolutions and for 1 inch drill 95 revolutions. Others recommend .002 to .005 inch per revolution. A revised table follows :

SPEED OF DRILLS AND TAPS.

Diam. of drill in inches.	DRILL SPEED IN			*TAP SPEED.		
	Soft steel.	Cast iron.	Brass.	Steel.	Cast iron.	Brass.
$\frac{1}{16}$	1800	2000	3500			
$\frac{1}{8}$	900	1000	1800			
$\frac{3}{16}$	600	700	1200			
$\frac{1}{4}$	450	530	900			
$\frac{5}{16}$	350	425	700			
$\frac{3}{8}$	300	350	600	60	75	100
$\frac{1}{2}$	225	260	450	45	60	80
$\frac{5}{8}$	180	210	360	30	60	75
$\frac{3}{4}$	150	175	300	25	45	65
$\frac{7}{8}$	130	150	260	20	30	50
1	110	130	225	15	20	40
$1\frac{1}{8}$	100	120	200			
$1\frac{1}{4}$	90	110	180			
$1\frac{3}{8}$	80	95	160			
$1\frac{1}{2}$	75	90	150			
$1\frac{5}{8}$	70	80	140			
$1\frac{3}{4}$	60	75	120			
2	50	65	100			

*Tap speed recommended by Granger Foundry and Machine Co., Providence, R. I.

Chapter XIII.

Speeds of Grindstones.

Grindstones are usually run too slow to give best results and a little data may be of use.

Ohio stones will safely stand a surface speed of 2500 feet per minute, while a Huron stone can be run at 3500 to 4000 feet per minute with safety, the smaller figure being advised.

As we know from Chapter IV that a stone one foot in diameter has a circumference of 3.1416 feet, then if we divide 3500 by 3.1416 we have 1114 as the number of revolutions per minute a Huron stone of this diameter must make, to have a surface speed of 3500 feet per minute. Dividing 2500 by 3.1416 we obtain 795 revolutions per minute for an Ohio stone one foot in diameter.

Calling the permissible speed of a Huron stone one foot in diameter, or 1114 revolutions per minute, and of an Ohio

stone 795 revolutions, we can find the correct speed for any diameter by dividing the constants above by the diameter in feet. Taking a Huron stone $3\frac{1}{2}$ feet in diameter, we have $1114 \div 3.5 = 318.2$ revolutions per minute.

This may be objected to as being apt to throw water, but as we are after economy in grinding we can, if we will, prevent the throwing of water by a brush or wiper on the "up" side of the stone.

Emery Wheels.

The speed generally advised by makers is 5500 feet per minute, from which we can easily calculate the speed for any diameter by multiplying the diameter in inches by 3.1416, and after reducing to feet, dividing 5500 by it.

A 10-inch wheel would give us $10 \times 3.1416 = 31.416$ inches or 2.6 feet.

$$5500 \div 2.6 = 2108 \text{ revolutions.}$$

Working this down to an everyday basis we can say that a wheel 1757 feet in diameter ($5500 \div 3.1416$) could only revolve once per minute to make the required speed, or reversing the proposition

a wheel *one foot* in diameter must revolve 1757 times to make 5500 feet per minute.

As we speak of wheels mostly in inches however, let us reduce this to inches by multiplying by 12 and we have $1757 \times 12 = 21084$ inches.

A wheel 21084 inches in diameter must revolve once per minute or a *one inch* wheel revolve 21084 times per minute for the right speed.

So keeping this for a constant number we can find the correct number of revolutions by dividing the constant by the diameter *in inches*, or having an emery grinder which runs at a fixed speed, we can find the right diameter wheel to use to get best results.

Having an 8 inch wheel we wish to know how fast it must run to have the required surface speed?

$$21084 \div 8 = 2635 \text{ revolutions.}$$

An emery grinder spindle runs 1800 revolutions per minute, what diameter wheel shall we use?

$$21084 \div 1800 = 11.7 \text{ inches.}$$

The grindstone figures can be worked the same way and gives $2500 \times 3.1416 \times$

12=9550. And $3500 \times 3.1416 \times 12 =$
13370, for the Ohio stone and Huron
stone respectively.

Polishing Wheels.

Wood, leather covered,	7000	ft. per minute
Walrus hide,	8000	" "
Rag wheels,	7000	" "
Hair brush wheels,	12000	" "

Chapter XIV.

Principles of Square Root.

It may easily be imagined that once upon a time some person while investigating mathematical problems, possibly with nothing better than a handful of pebbles for instruments, made the great (for the time) discovery that while twelve times twelve pebbles was one hundred and forty-four pebbles, that one-half of twelve times one-half of twelve pebbles was not *one-half* of one hundred and forty-four pebbles, but was *one-quarter* of one hundred and forty-four pebbles. It may also be easily imagined that this mathematical investigator arrived at this conclusion by putting his pebbles in twelve rows of twelve each, and six rows of six each, forming two *squares*, one of which was evidently four times the size of the other by eye measurement, as well as containing four times as many pebbles by actual count.

After he had made a few of these *squares* it probably occurred to him that when he went to the post-office to get one hundred postage stamps, it wasn't necessary for him to count the whole hundred, but simply to count and see if he had ten on each *side* of his *square*; and finally, he probably fell into the unconscious habit of performing simple mental operations in extracting *square root*, by asking himself perhaps something as follows: "Now, I want to make a box to hold 144 eggs, each egg to be in a compartment by itself, the box to be a *square* box; how many compartments on each *side* of the *square* box must I have to hold the 144 eggs? Why 12, of course."

About this time Euclid made the discovery that in a right-angled triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides of the triangle.

That is, if one *square* of 36 pebbles is placed in such a position regarding another *square* of 64 pebbles, that two of their *sides* form a right-angled triangle, it will be seen that one side of another

square of 100 pebbles will exactly form the hypotenuse or third side of the triangle, the square of 100 pebbles being equal to the sum of both the other squares; that is, 36 and 64 make a total of 100 (see the figure on page 76, each small square representing a pebble).

Now, it *might* be that what is true of a right-angled triangle of the above dimensions, would not be true of any other triangle. If we take two squares, for instance, of 25 and 16, the sum of which is 41, we cannot come to any conclusion whatever on this particular question, because we cannot arrange our 41 pebbles in the form of a square.

But Euclid proved to a dead certainty that this would hold true, no matter what quantities or numbers entered into the problem, and to deal with this and other things to follow it is now necessary to begin to consider the idea of *unity*; that is *one*; one pebble, one *bushel* of pebbles, one *barrel* of pebbles, one *half ton* of pebbles, one *half* of a pebble. That twice *one* are *two*; twice *one pebble* are *two pebbles*; twice *one bushel* *two bushels*; twice

one barrel *two* barrels; twice one half ton *two* half tons; twice one half of a pebble *two* halves of a pebble; whether actually in two pieces or in the form of one whole pebble. Every thing in the world taken together makes *one* world; the smallest pebble in the world may be considered as being composed of two halves, four quarters, or a thousand thousandths, or in any other way we choose to divide it, or may be considered as *one half* of *two* pebbles.

The truth that in a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides being accepted, it of course follows that if we can find some way to calculate just what the side of a square of these 41 pebbles would be, supposing that they were ground to powder and put in a square, or when the number is too large to make an easy mental calculation (as when you count the sheet of 100 stamps), we can solve many problems that come up in machine shops, such for instance as the exact angle to set a grinding machine to grind a cutter for screw

threads, supposing that the cutter is to be held in a holder made to hold the cutter with a standard *clearance*. In other words, many problems coming up in fine machine work, necessitating a knowledge of how to *extract square root*.

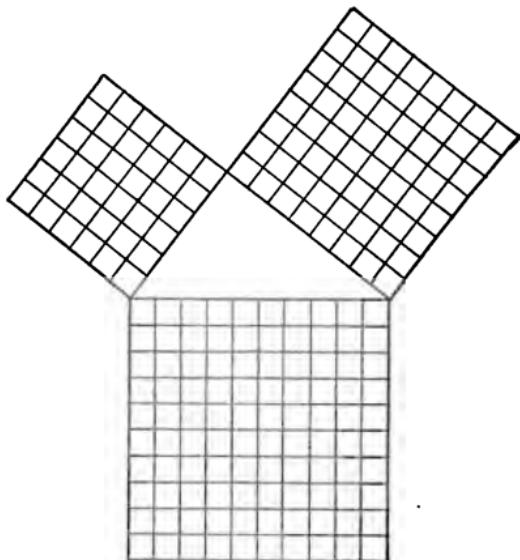


FIG. 8.

Some of these investigators found while playing with their pebbles that the law of squares was a universal law; that his square of 12 pebbles on a side was *always* 144 pebbles, whether he *considered* it as 12 on a side, or 11 and 1 on a side,

or 10 and 2 on a side, or 9 and 3 on a side, and so on through the scale, and they also found that when they did consider their sides of squares as being made up of two quantities, that a universal law held good that the square was always made up as follows: The square of one quantity, plus twice one quantity multiplied by the *other*, plus the square of the *other* quantity; or in the algebraic language representing one quantity (no matter which or what size) by a , and the other by b , then the square of a plus b is equal to a square, plus two $a b$, plus b square, or in algebraic signs $(a+b)^2=a^2+2 ab+b^2$.

Let us try and see how it comes out, considering 12 as 11 and 1 (or 11 plus 1).

11 squared	121
Twice 11 times 1	22
1 squared.....	1
Total.....	<u>144</u>

Considering 12 as 10 plus 2:

10 squared	100
Twice 10 times 2	40
2 squared.. ..	4
Total.....	<u>144</u>

Considering 12 as 9 plus 3:

9 squared.....	81
Twice 9 times 3.....	54
3 squared.....	9
Total.....	144

Having found out how the square is made up, it is easy enough to pull it to pieces again, or in other words to *extract the square root*, by simply reversing the process by which it was considered the square was made up.

Before proceeding further, we must understand one simple law of multiplication and division—multiplication being simply *supplying* a certain *quantity* a certain number of *times*, same as our ancient friend did when he *supplied* 12 pebbles 12 *times* to make his 144 pebbles; and division being simply the *taking away* a certain quantity a certain number of times.

Supplying 12 pebbles 12 times is multiplying 12 by 12, and dividing 144 by 12 is taking 12 lots of 12 pebbles from 144 pebbles, in which case we have no pebbles remaining in the original lot of 144. It follows then, that when a certain quantity is made up by multiplying two *other* quan-

tities together, if the certain quantity is divided by either of the other two quantities that went to make it up, that the result must be the other one of the two quantities; that is if we multiply 4 by 5, making 20, if we divide 20 by 5 the result must be 4, or if we divide 20 by 4 the result must be 5.

We can now pick the square 144 to pieces as follows, assuming it to be made up of sides of 11 and 1:

Take away from 144 the square of 11:

$$\begin{array}{r} 144 \\ \text{The square of 11} \dots \dots \dots 121 \\ \hline 23 \text{ remaining} \end{array}$$

Take from the 23 remaining the square of 1:

$$\begin{array}{r} 23 \\ \text{The square of 1} \dots \dots \dots 1 \\ \hline 22 \text{ remaining} \end{array}$$

Take away from 22 twice 11 times 1:

$$\begin{array}{r} 22 \\ \text{Twice 11 times 1} \dots \dots \dots 22 \\ \hline 00 \end{array}$$

Assuming the square 144 to be made up of sides of 10 and 2:

Take from 144 the square of 10:

144

The square of 10.....100

44 remaining

Take from the 44 remaining the square of 2:

44

The square of 2.....4

40 remaining

Take from 40 twice 10 times 2:

40

Twice 10 times 240

00

It will be found that *any* square can be made up and pulled down in the same way; of course it is simple enough when we know how it is made up, to pull it down again.

Now, as it is an accepted custom (*not a mathematical principle*) that numbers increase in value by ten for each place to the left as they are written, let us consider that 144 is the square of something composed of *units* and *tens* (we already *know* it to be composed of *one ten* and *two units*, but this knowledge must not enter into the operation which we are

about to perform), and as the square of units *cannot* be greater than tens (9 largest unit, 81 its square), and as the square of tens cannot be greater than thousands (99 largest ten, 9801 its square), we will separate the number 144 into tens and thousands (these being the squares of units and tens) by following the custom of "pointing off" from the units number into "periods of two figures each."

We have now divided our lot of 144 pebbles, if you please, into two lots (or "periods"), one lot consisting of 100 pebbles and the other lot consisting of 44 pebbles (or 4 tens pebbles and 4 units pebbles), simply because it is *customary*, as explained before, to write numbers in units, tens, hundreds, etc., etc.

The left-hand "period" of 1, then, represents a *unity of hundreds*, that is *one hundred—one hundred pebbles*. Let us take away from this period of 1 (no matter now *one what*) *the largest square there is in it*, which is evidently 1, we have now *pulled out the square of the tens of which the square number 144 was made up*. That is, we have extracted the square

root of all the tens making up the thousands "period" and find it to be *one ten*; we will therefore put down this one ten thus: 1, *not forgetting that it stands in the TENS PLACE*

Now let us go back to the principle of multiplication and division as touched on before:

Having found what the square root of the tens is, and knowing the way that the square is made up, we can now deal with the remaining 44.

Having considered the *root* to have been made up of *units* and *tens*, let us call the tens a and the units b , and look at the algebraic formula again: $(a+b)^2=a^2+2ab+b^2$.

We have already dealt with the a^2 and set down its root a , in the form of a figure 1 (in the tens place), and now considering the remaining 44 as being also units and tens (4 units and 4 tens), let us see what we can do towards picking out the $2ab$ of the algebraic formula. We know what the a is; it is 1, and if we divide the tens of the remaining 44 by $2a$ (which in this case is 2), it will give us a

hint of what b is; thus we get a hint that b is 2; we therefore consider that it is 2, and see how the experiment comes out. Having already taken away the square of the tens, which is the a^2 of the formula, if b is 2, and we multiply it by itself, it will give us 4 units and fulfill the b^2 of the formula, and if we multiply it by 2 a , which is 20, it will give us twice the tens multiplied by 2 or the 2 a of the formula, this being in this case 40, or 4 *in the tens place*.

That is, the $2 a b + b^2$ of the formula is made up of $2 a$ multiplied by b , and b multiplied by b , which is of course b^2 , and, referring back to the *principle* of multiplication and division explained before, dividing the $2 a b$ of the formula by the $2 a$, which we already know, *must* give us the b , if the number 144 is a perfect square, which we know it to be in this case.

Practically if no number can be found by trial that will meet the conditions of b , the largest that will go must be taken, and the remainder considered as a decimal fraction, and the operation repeated until the root is extracted as far as wanted.

The correctness of this is manifest when we consider that one ten is equal to ten units, and one unit is equal to ten tenths, and one tenth to ten hundredths, etc., each place to the left increasing the value of a figure, the decimal point having no value, but simply shows where *unity begins*.

A comparison of these principles and explanations, step by step with the operation of extracting square root as done by the conventional rule, cannot fail to make the subject clear, and when once the subject *is* clear, there is less liability of mistakes when doing a problem by the rule, to say nothing of the advantage of being able to get along without the rule if the book is mislaid or the memory weak. When the principle of extracting roots is once mastered it is a fascinating amusement as well as valuable practice, to extract 4th, 5th, 6th, etc., roots for which no rules are usually to be found.

Chapter XV.

Principles of Cube Root.

Assuming that it is understood how a *square* is made up and the principle on which square root is extracted, as explained in the previous chapter on *square root*.

We will proceed to investigate the manner in which a *cube* is constructed. The cube of 12 (12 times 12 times 12, or as expressed in signs, $12 \times 12 \times 12$) is 1,728, and considering that the 12 is composed of 10 and 2 (on account of the *custom* of giving a value of ten times what the figure itself represents, for each place to the left occupied by the figure, as explained in the chapter on square root), we find the cube of 1,728 to be made up as follows:

10 cube,	-	-	-	-	-	-	1,000
3 times 10 square times 2,	-	-	-	-	-	-	600
3 times 10 times 2 square,	-	-	-	-	-	-	120
2 cube,	-	-	-	-	-	-	8
Total,	-	-	-	-	-	-	1,728

"Pointing off" the number 1,728 into "periods of three" (for the same reason that we point off into periods of two in square root), we proceed to extract the largest cube from the left hand period, in this case 1, the cube root of which is evidently 1 also, so that we now know we have found the 1 *ten* that went to make up the cube 1,728, and as the cube of the 1 *ten* is 1,000 we now must consider the remaining 728, which we know to be made up 3 times 10 square times 2, plus 3 times 10 times 2 square, plus 2 cube, as shown before. But as two is the number we are now seeking for, we must now assume that we do not know what it is, in order to be able to find it when we really do not know in actual practice.

Whether it is 2 or any other number we know it cannot be a very large number, as it *must* be *units* (as we have already found what the cube root of the *tens* is), and cannot therefore be over 9.

It follows then that the remaining 728 must be made up *principally* of 3 times 10 square, plus 3 times ten, multiplied by something which will make *nearly* 728,

and by using this 3 times 10 square, plus 3 times 10, for a *trial divisor*, we get a *hint* of what the "something" wanted is.

As this sum (330) will go into 728 a little over twice, we think that 2 is the number we are looking for, and to see if it really is the number we want, we must carry it through with the rest and see how we come out.

As we know the remaining 728 to be made up of 3 times 10 square times 2, plus 3 times 10 times 2 square, plus 2 cube, we know also that if we remove the factor 2 from these quantities, that is divide them by 2, we shall obtain a quantity, which, being multiplied by 2, will give us the original quantities back again; this being self-evident.

Dividing these quantities by 2, we obtain 3 times 10 square (the 2 left out) plus 3 times 10 times 2 (one of the 2's left out) plus 2 *square* (one of the 2's left out again).

By making a divisor of the sum of these quantities, which amount to 364, we find it goes exactly twice into the remaining 728, and therefore know that **2 is**

really the *units* figure that we have been looking for.

To reduce to a formula: The cube of $a+b$ is $a^3+3a^2b+3ab^2+b^3$ ($a=10$ and $b=2$ in this case), after taking away the a^3 we evidently have remaining $3a^2b+3ab^2+b^3$. As we do not know what b is, we take $3a^2+3a$, which is what remains with the b left out altogether, for a *trial divisor*, and by assuming the approximate quotient to be the b that is sought, we take $3a^2+3ab+b^2$, which is $3a^2b+3ab^2+b^3$ divided by the b , and multiply it by the b back again, to see if the b we have assumed is really the b we have been looking after.

In the case of 1728 we find that it completes the cube, and that b is really 2 and so know that we are right.

Therefore (knowing that we are right), if there should be a remainder after taking the result of this final multiplication out of what is left of the original number, we would know that the number was not a perfect cube, and would take what is left and annex ciphers for another period, or as many more periods as required for the degree of accuracy needed, same as in square root.

Chapter XVI.

Foundation Principles.

To be thoroughly independent of *rules* for extracting roots (and a great many other mathematical calculations as well), we must consider the idea of *factors*.

When we multiply 3 by 2 we have 6 for a result, and we say 3 and 2 are *factors* of 6; multiplying again by 2 we get 12, and say that 6 and 2 are *factors* of 12, or we can say that 2 and 2 and 3 are factors of 12; or multiplying 12 by 12 we get 144 and say that 12 and 12 are factors of 144, or we can say that 2 and 2 and 2 and 2 and 3 and 3 are factors of 144, this being represented in arithmetical signs as follows:

$$2 \times 2 \times 2 \times 2 \times 3 \times 3 = 144.$$

This is called an *equation* because something is represented as being *equal* to something else.

If we start and reverse the operation and divide 144 by 2 we have 72 as a result, and find that *one less* 2 on the left

hand side will make the equation true, thus:

$$2 \times 2 \times 2 \times 3 \times 3 = 72.$$

That is, we can take away one of the factors 2 from the left hand side of this equation, and divide the right hand side by 2, and still have an *equation*: that is, one side will still be *equal* to the other side.

It follows then, that by taking one of the factors 2 from the left hand side, and dividing the right hand side by 2, we have done the same thing to both sides, because if we had not, they would no longer be equal.

That is, dividing 144 or any other number, by 2 or any other number, is simply taking the factor 2 (or whatever other number it may be), from the first number, no matter how the first number is represented.

Or in other words, taking the quantity $2 \times 2 \times 2 \times 2 \times 3 \times 3$ (which we happen to know is equal to 144) and removing one of the factors 2 from it, we have *divided the whole quantity* by 2.

A little more reasoning along this same line will show us that *dividing*

factor by a certain number divides the whole quantity by that number, or multiplying a factor by a certain number (or quantity) multiplies the whole quantity by that number (or quantity).

In arithmetic we can consider a certain number as representing a certain thing; that is, we can take the number 1, and consider that it stands for 1 ton of coal, and after going through our calculations, we know that the result, whatever it is, is also to be considered as tons of coal. So in algebra, a certain sign or letter may be considered as a certain number or quantity of anything and the sign or letter is multiplied or divided, etc., through the calculation, and when the calculation is completed, we know that this sign or letter represents in the result the same thing that it did at the start: If we say that a represents a ton of coal, and when the calculation is completed, we have a result of $144a$, we know that this means 144 tons of coal.

It would be easy enough to carry the number 1 through any calculation (no matter now whether 1 ton of coal or 1

something else), but if we had the number 1,083,729,524,982, to deal with it would be quite a task to carry it through a long calculation. A slight knowledge of algebra allows us to consider that a or b , or c , represents this large number, or any other number, or thing, and carry the *letter* through a calculation (it is *customary* to use the first letters of the alphabet to represent *known* quantities, and the last letters of the alphabet to represent *unknown* quantities, but it is not necessary to follow this custom, as we can as well use a picture of a ton of coal, to represent the ton of coal, or the above number of tons of coal, if we only stick to the same thing until the calculation is finished).

If then we had a large number like the above to deal with, it would evidently be easier to say in starting:

$$a=1,083,729,524,982$$

and take the a through the calculation; then if for instance we got $3a$ as the result of the calculation, we would know that 3 times 1,083,729,524,982 was our answer, thus being obliged to multiply this large number but once in the whole calculation.

which reduces the chances of error, as well as being easier and quicker.

In algebra, contrary to arithmetic, the position to the right or left, of a letter or sign has nothing to do with its value, and two or more letters side by side means that these letters are *multiplied together*, or in other words that they are *factors*.

The expression "*aa*" then, means that *a*, whatever it represents, is multiplied by *a*, and if we assume that *a* represents 12, we then know that "*aa*" represents 144.

But as any quantity multiplied by itself becomes *square*, the expression "*aa*" is equivalent to the expression "*a square*," and for the same reason the expression "*aaa*" is also evidently equivalent to the expression "*a cube*."

It is easier and quicker (besides being customary) to write *a square* thus, a^2 , instead of "*aa*", and *a cube*, a^3 , instead of "*aaa*".

When this is understood, we can take another step and instead of saying $a=12$, we can say $a=10$ and $b=2$, then we can

go ahead and say a plus $b=12$ or using the regular arithmetical sign for plus (addition) we write it thus:

$$a+b=12$$

It then follows that $a+b$ multiplied by itself will be equal to 12 multiplied by itself, or in other words that $a+b$, square, is equal to 12 square, and that (knowing 12 square to be 144) $a+b$, square, is equal to 144.

We can now multiply the expression $a+b$ by itself, the operation being very much like multiplication of numbers in arithmetic:

First (as in arithmetic) we set the quantities to be multiplied one under the other thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline \end{array}$$

b multiplied by b will evidently (from what has already been explained) become b square, written b^2 , so after the result of this first step is written down, the calculation would appear thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline b^2 \end{array}$$

Multiplying a by b would give us ab which we also set under the line, same as in arithmetic, thus :

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \end{array}$$

We have now multiplied $a+b$ by b and must start to multiply $a+b$ by a as follows :

b multiplied by a is evidently ab (the position of the factors not altering their value, so for convenience in adding we write it ab instead of ba) so (also for convenience in adding) we set this ab under the other ab which we got a first by multiplying a by b , thus :

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \\ ab \end{array}$$

And a multiplied by a is evidently a^2 , which we also set down thus :

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \\ a^2+ab \end{array}$$

We now (same as in arithmetic), add

the results of multiplication together, for the answer: ab added to ab is evidently *two ab*, which is written "2ab," so that the complete operation now appears thus:

$$\begin{array}{r} a+b \\ a+b \\ \hline ab+b^2 \\ a^2+ab \\ \hline a^2+2ab+b^2 \end{array}$$

$a^2+2ab+b^2$ is the formula given in the chapter on "square root" on pages 77 and 82.

By multiplying this again by $a+b$, we will evidently get the *cube* of $a+b$, which is the formula used in the article on cube root, thus:

$$\begin{array}{r} a^2+2ab+b^2 \\ a+b \\ \hline a^2b+2ab^2+b^3 \\ a^3+2a^2b+ab^3 \\ \hline a^3+3a^2b+3ab^2+b^3 \end{array}$$

If we should multiply this again by $a+b$ we should get a formula which would allow us to extract the *fourth* root, and so on.

A thorough understanding of these

foundation principles, and of the previous chapters on square root, and cube root, makes us independent of any written rules for extracting square, cube, or *any other root.*

Chapter XVII.

Principles of Screw Cutting.

Every mechanical paper is periodically asked by its readers for a "rule" for selecting change gears for screw cutting. Thousands of "rules" have been given, and books of "rules" have been published, but they are all worse than useless, because any one who does not understand the *principle* of screw cutting on lathes, is pretty apt to use a rule that has been made for some certain lathe, in connection with some other lathe, and as lathes are not all alike the result is far from satisfactory. Even a rule for a certain lathe is bad, because, not understanding the principle and depending on the rule, when a mistake is made in figuring, as sometimes will occur with the most expert, the person's *judgment* does not call attention to the error as it would if the subject were thoroughly familiar.

If the leading screw of a lathe has four threads to one inch, it is evident that the lathe carriage, when engaged with the screw, will move one inch when the screw has made four revolutions; if five threads, the carriage will move one inch when the screw has made five revolutions, and so on. Again, if the *spindle* of the lathe (and a piece of work revolving with the spindle) makes four revolutions while the carriage moves one inch, it is evident that four threads to one inch will be cut on the piece of work in the lathe (provided, of course, that the lathe is set up for screw cutting), or if the spindle makes five revolutions while the carriage moves one inch, five threads to one inch will be cut, and so on. By following this course of reasoning to its conclusion, we find that the *ratio* that exists between the number of threads to one inch of the leading screw, and the number of threads to one inch that it is desired to cut, *must also exist in the train of gearing between the spindle and the leading screw*, and incidentally it follows that when this ratio cannot be obtained with the gears at hand, the desired

thread cannot be cut. This will be referred to again later.

Now for the practical application: First *find the ratio* between the number of threads desired to be cut and the number of threads of the leading screw; this is found by dividing one by the other. If, for instance, it was desired to cut four threads to one inch on the lathe, the leading screw of which had four threads to one inch, we find the ratio, dividing four by four, to be *one*. That is, the ratio in the whole train of gears between the spindle and the leading screw must be *one*, or in other words and in the language of the shop, we must use *even gears*, *provided there is no compounding* in the intermediate gearing between the spindle and the leading screw; but nearly all lathes have these compounds of gearing, and this is why a *rule* is worse than useless. Again, if it is desired to cut five threads on the lathe with four threads in the leading screw, we find the *ratio* to be one and one-fourth, and we must accordingly select two gears, in which the number of teeth in one is one-fourth more than the number

of teeth in the other; and here again the *judgment* guides safely when a rule would be confusing.

To cut five threads with four threads on the leading screw, it is evidently necessary that the *spindle* should revolve *faster* than the *leading screw*, and it follows that the gear on the *spindle* must be the *smaller* of the pair selected, for reasons that are so simple and self-evident that I do not know of any way to explain or prove the statement: *always provided, as far as we have gone, that there is no compounding in the train of gearing.* But, practically as mentioned above, the compounding must usually be taken into consideration.

Of four lathes by four different makers that I have been looking at, but one has the first change gear directly on the spindle; the three others use a separate shaft for the first change gear, and in each case this shaft is so fixed with permanent gearing that it revolves only one-half as fast as the spindle; a rule then, that gives a result of a certain gear for the spindle and of another certain gear for the

screw, if applied to three out of these four lathes, would give the practical result of twice as many threads as it was desired to cut.

The easiest way to provide for this particular construction in a lathe (and it is a very common construction) is to assume that the leading screw has twice as many threads to one inch as it really has. Of course if the lathe was of such construction that the shaft that takes the first change gear made only one-third as many revolutions as the spindle, it would be necessary to assume that the leading screw had three times as many threads to one inch as it really has, and so on; but, as stated above, the two-to-one construction is the most common on medium sizes of lathes.

Having assumed, in this case, the number of threads on the leading screw to be twice as many to one inch, the problem then is reduced to the simple one first stated; that is, the ratio that exists between the number of threads desired to be cut, and the *assumed* number of threads of the leading screw, must also exist in the gearing between the first change gear shaft and

the leading screw. And when there is no *compounding* of gears between the first change gear shaft and the leading screw, this ratio must exist *between the two gears selected to go on the first change shaft and the leading screw respectively*. Any gears between these two simply go to bridge the distance between the change gears selected, as it is evident that when there is no *compounding*, one tooth motion of the first gear will result in only one tooth motion of the last gear no matter how many or what sizes of gears are between.

Taking for example the lathe mentioned above that takes the first change gear directly on the spindle; the change gears on this lathe have the following numbers of teeth respectively: 16, 20, 24, 28, 32, 36, 40, 44, 46, 48, 56, 64, 72, and the number of threads to one inch of the leading screw is 4. There is a cast brass plate attached to the head containing a list of numbers of threads and the number of teeth in gears to go on the spindle and screw respectively, in order to cut these threads, and this is the most common way in which screw cutting lists are furnished

with lathes. This lathe has a large hole through the spindle, in consequence of which the holes in the change gears that go on the spindle are extra large, and but two of these gears with large holes are provided, these being with 32 and 64 teeth respectively. This of course reduces the total number of different threads that might be cut if any gear would go on the spindle, but the lathe is so designed that any common thread wanted, except 13, may be cut, the list being as follows: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 11½ (for pipe threads), 12, 14, 16, 18.

Now, although this lathe takes the first change gear directly on the spindle, it does not take the last change gear directly on the screw, but on a stud that is connected with the screw, and is reduced by gearing so that the screw moves but half as fast as the stud. This gearing is out of sight under the head, and might very easily pass unobserved, and this shows the practical advantage of measuring a thread after the first light chip has been taken, to be sure that no mistake has been made in figuring or placing

change gears. The effect of this gearing is of course the same as if the reduction had been between the spindle and first change gear; that is, to make it practically a lathe with twice as many threads in the leading screw as it really has, and with this understanding we may now investigate some practical examples.

To calculate the gears to cut two threads per inch on this lathe, we divide 8 (the *assumed* number of threads in leading screw, the *real* number being 4, as mentioned above) by 2 (the number desired to be cut), and find the *ratio* to be 4; we must, therefore, select a pair of gears the ratio of which is also 4, and as only the gears numbered 32 and 64 will go on the spindle we must have either 8 or 16 teeth in the gear on the screw; there being no 8 gear with the lathe, and of course practically no change gears with so few teeth as 8 made, we must use the 16 gear and the 64 gear, these being 1 to 4, the proportion required.

Suppose we wish to cut 13 threads on this lathe (13 being the Franklin Institute standard for $\frac{1}{2}$ inch diameter), we find

the ratio between 8 and 13 to be $1\frac{5}{13}$, and it follows, as before explained, that we must select two gears, one of which has $1\frac{5}{13}$ times as many teeth as the other. Common sense, to say nothing of mathematics, teaches us that if we are to select a gear with $1\frac{5}{13}$ times as many teeth as *another* gear, that *the other* gear must have some number of teeth *that can be divided by 13*, and as there is no gear in the list that can be divided by 13, it follows with mathematical certainty that 13 threads cannot be cut on this lathe with the gears that come with the lathe.

If this simple point is once understood it saves lots of trouble in the shop. An example of fractional thread cutting, to illustrate the principle, may not be out of place at this time. Suppose that it is desired to cut on this lathe $5\frac{3}{4}$ threads to one inch; no such number of threads appears on the list attached to the lathe. The first question is, can it be done? To answer we proceed thus: Multiply $5\frac{3}{4}$ and 8 each by some number that will reduce $5\frac{3}{4}$ to a whole number, as multiplying *both* by the *same* quantity will not change.

the *ratio*. Every school-boy knows that in this case 4 is the smallest number that will do this, because 4 is the denominator of the fraction that it is desired to eliminate; we thus obtain the two numbers 23 and 32, and dividing one by the other we find the ratio to be $1\frac{9}{23}$. We must therefore select two gears, one of which has $1\frac{9}{23}$ as many teeth as the other, and it follows that, as stated before, we must find a gear the number of teeth in which can be divided by 23; the only such gear in the list is 46, and 46 multiplied by $1\frac{9}{23}$ is 64, the other gear, which we also find in the list.

When the *principle* of this is thoroughly understood, it is safe to take some short cuts, and this might have been done in the last example, as follows: After getting the two numbers 23 and 32, the ratio will evidently be preserved if they are both again multiplied by some number that will give us two numbers corresponding to the numbers of teeth in two gears contained in the list; such a number in this case being 2, the result is 46 and 64, the same as obtained by the longer

process. Sets of change gears are designed to increase by a certain number, the number in this list being 4, except that there is a break where the 52 gear is left out, and that the gear 46 is added for the purpose of cutting $11\frac{1}{2}$ threads. If we had the 52 gear, we could cut 13 threads on this lathe, and I cannot see why this was left out.

Now, if we multiply the number of threads desired to be cut and the assumed number of threads on the leading screw, both by the number by which the list of change gears increases, we can usually get, first time trying, two gears that are in the list, and as these will evidently be the same ratio (being the result of multiplying by the same number) as the number of threads to be cut, and the assumed number of threads in the leading screw, they will be right to cut the thread wanted. Example: To cut 18 threads $18 \times 4 = 72$ and $8 \times 4 = 32$, the gears required, and this method is the shortest and easiest way that I know of, and may be used when it is *known* by the screw cutting list or otherwise that the

number of threads per inch wanted can be cut on the lathe to be used.

Of course it saves work in calculating these gears (or anything else) to reduce all fractions as fast as they come to their *lowest* terms.

On very large lathes (and sometimes on ordinary sized lathes when very fine or very coarse threads are to be cut) it is necessary to *compound* the change gearing, which is usually done by having a stud with one small gear and one large gear, somewhere between the "gear on spindle" and the "gear on screw." When this is done the number of threads in leading screw must evidently be multiplied by the *ratio* that exists between the two gears on the intermediate stud (as well as by the ratio of the permanent gearing between the spindle and first change gear stud, or between the last change gear stud and the leading screw) in order to get the correct number of *assumed* threads on leading screw.

Chapter XVIII.

Handy Ways for Calculating.

When squaring (or multiplying it by itself) any mixed number (whole number and a fraction) whose fraction is $\frac{1}{2}$ it is well to know that this can be done mentally as follows:

Add *one* to one number, multiply by the other, and add $\frac{1}{4}$ to answer.

Take $3\frac{1}{2} \times 3\frac{1}{2}$; $3+1=4$, $4 \times 3=12$
 $+ \frac{1}{4}=12\frac{1}{4}$ answer. Or $9\frac{1}{2} \times 9\frac{1}{2}=9$
 $+ 1=10 \times 9=90 + \frac{1}{4}=90\frac{1}{4}$.

A quick and easy way to divide any number by $12\frac{1}{2}$ is:

Multiply by 8 and "point off" two places.

Example: $\frac{250}{12\frac{1}{2}}=250 \times 8=2000$ and pointing off two places (always from the right) we have 20.00 as the answer.

A handy rule for squaring any number mentally is:

Subtract the number from the next higher *tens* number, subtract the difference

from the original number; multiply this result by the *tens* number used and add the square of the difference.

This sounds hard but it isn't, and can be readily acquired so that any number up to 100 can be squared mentally, easily and quickly.

Take 17, the next higher *tens* number is 20. $20-17=3$. $17-3=14$. $14 \times 20=280$. $3 \text{ squared} = 3 \times 3 = 9$. $280+9=289$, the square of 17.

Take 26. Next higher *tens* number is 30. $30-26=4$. $26-4=22$. $22 \times 30=660$. $4 \times 4=16$. $660+16=676$, the square of 26.

One more example will show its use in squaring large numbers.

Take 81. Next higher *tens* number is 90. $90-81=9$. $81-9=72$. $72 \times 90=6480$. $9 \times 9=81$. $6480+81=6561$, the square of 81.

This is a larger number than it is often necessary to square mentally, but a little practice makes it an easy matter, and it's often handy in comparing areas of pipes and cylinders.

Chapter XIX.

Allowances for Running and Force Fits.

RUNNING FITS.		FORCE FITS.	
Diam. of Bearing.	Diam. of Shaft.	Diam. of Hole.	Diam. of Shaft.
1.....	.999	1.....	1.001
2.....	1.998	2.....	2.003
3.....	2.997	3.....	3.005
4.....	3.9965	4.....	4.006
5.....	4.9963	5.....	5.007
6.....	5.996	6.....	6.008
7.....	6.9958	7.....	7.0085
8.....	7.9958	8.....	8.009
9.....	8.9957	9.....	9.01
10.....	9.9956	10.....	10.0105
11.....	10.9955	11.....	11.011
12.....	11.9954	12.....	12.0115
13.....	12.9953	13.....	13.012
14.....	13.9952	14.....	14.013
15.....	14.9951	15.....	15.014
16.....	15.995	16.....	16.0145
17.....	16.9949	17.....	17.015
18.....	17.9948	18.....	18.0155
19.....	18.9947	19.....	19.016
20.....	19.9945	20.....	20.017

Drive fits allowances are one-half that of
force fits. BUILDERS IRON FOUNDRY.

Chapter XX.

Metric System of Measurements.

When the French were stirring things up by their revolution, they also made a new system of measuring, which was adopted in 1795. Discarding the inch, they took for a basis what was supposed to be one ten-millionth part of the distance from the equator to the pole. This they called a METER.

The subdivisions have Latin prefixes, while the larger measures are taken from the Greek. These are as follows:

The unit

of weight is called the GRAM,
of liquids the LITER, and
of land measure the ARE.

Milli = $\frac{1}{1000}$.

Deka = 10.

*Centi = $\frac{1}{100}$.

Hekto = 100.

Deci = $\frac{1}{10}$.

Kilo = 1000.

*This is pronounced as though it were spelled "sonti," with the *o* same as in *on*. The rest are pronounced as spelled, with a long *i* as *y* in *kilo*.

and a table would be

10 millimeters	=	1 centimeter.
10 centimeters	=	1 decimeter.
10 decimeters	=	1 meter.
10 meters	=	1 dekameter.
10 dekameters	=	1 hektometer.
10 hektometers	=	1 kilometer.

The LITER is one cubic decimeter;
the ARE is one square dekameter;
the GRAM is one cubic centimeter of water.

As will be seen, everything goes by tens, which makes all calculations easy, and the exact relation between the different measures is responsible for its wide adoption. If the unit selected had been the standard English inch, so as not to upset everything in the way of gages and scales which we now have, there would be much less opposition to its universal adoption. The ease of calculating is certainly in its favor, as everything goes by tens, and after learning the meaning of the different prefixes and the names of the units, no tables are necessary.

A study of the table prepared by Mr. C. W. Hunt, which appears on page 116, will show the relation between the metric

and our own systems, and show that a millimeter (the smallest measure of the table) is entirely too large for fine machine work, being nearly four one-hundredths of an inch. A milli-inch—if we had one, would be our much used thousandth of an inch.

One good feature of the decimal part of the metric system is that we know in an instant the relation between any number and the unit. A DECI-LITER is, of course, one-tenth of a liter, while a DEKA-GRAM is ten grams. A HEKT-ARE is one hundred ares, and a MILLI-ARE is one one-thousandth of an are, while a KILO-METER is one thousand meters.

We do not believe that the metric system will be universally adopted in the shops of this country, but every mechanic wants to know about it, and the appended tables will be found useful.

METRIC CONVERSION TABLE.

Arranged by C. W. Hunt, New York.

Millimeters $\times .08987$ = inches.	Liters $\div 28.316$ = cubic feet.
Millimeters $\times .25.4$ = inches.	Hektoliters $\times 8.531$ = cubic feet.
Centimeters $\times .3837$ = inches.	Hektoliters $\times 2.84$ = bushels (2150.42 cu. in.)
Centimeters $\div 2.54$ = inches.	Hektoliters $\times 131$ = cubic yards
Meters $\times .39.37$ = inches. (Act of Congress.)	Hektoliters $\div .20.42$ = gallons (231 cu. in.)
Meters $\times 3.281$ = feet.	Grams $\times 15.432$ = grains. (Act of Congress.)
Meters $\times 1.094$ = yards.	Grams $\div 981$ = dynes.
Kilometers $\times .621$ = miles.	Grams (water) $\div 29.57$ = fluid ounces.
Kilometers $\div 1.6093$ = miles.	Grams $\div 28.35$ = ounces avoirdupois.
Kilometers $\times 3280.7$ = feet.	Grams per cu. cent. $\div 27.7$ = lbs. per cu. in.
Square Millimeters $\times .00165$ = sq. inches.	Joule $\times .7373$ = foot pounds.
Square Millimeters $\div 645.1$ = sq. inches.	Kilograms $\times 2.2046$ = pounds.
Square Centimeters $\times .185$ = sq. inches.	Kilograms $\div .35.3$ = ounces avoirdupois.
Square Centimeters $\div 6.451$ = sq. inches.	Kilograms $\div 1102.3$ = tons (2,000 lbs.)
Square Meters $\times 10.764$ = sq. feet.	Kilogram per sq. cent. $\times 14.223$ = lbs. per sq. in.
Square Kilometers $\times 247.1$ = acres.	Kilogrammeters $\times 7.233$ = foot lbs.
Hektare $\times 2.471$ = acres.	Kilo per Meter $\times .672$ = lbs. per foot.
Cubic Centimeters $\div 16.383$ = cubic inches.	Kilo per Cu. Meter $\times .0062$ = lbs. per cu. ft.
Cubic Centimeters $\div 3.69$ = fl. drachms. (U. S. P.)	Kilo per Cheval $\times .22.35$ = lbs. per H. P.
Cubic Centimeters $\div 29.57$ = fluid oz. (U. S. P.)	Kilo Watts $\times 1.34$ = horse-power.
Cubic Meters $\times 35.315$ = cubic feet.	Watts $\div .746$ = horse-power.
Cubic Meters $\times 1.308$ = cubic yards.	Watts $\div .7373$ = foot pounds per second.
Cubic Meters $\times 264.2$ = gallons (231 cu. in.)	Calorie $\times 3.9068$ = B. T. U.
Liters $\times 61.022$ = cubic in. (Act of Congress.)	Cheval vapent $\div .9863$ = horse-power.
Liters $\times 33.84$ = fluid ounces (U. S. PHAR.)	(Centigrade $\times 1.8$) $+ 32$ = degree Fahrenheit.
Liters $\times 2642$ = gallons (231 cu. in.)	Franc $\times .193$ = dollars.
Liters $\div 3.78$ = gallons (221 cu. in.)	Gravity Paris = 980.94 centimeters per sec.

**ENGLISH MEASURES WITH METRIC
EQUIVALENTS.**

INCHES IN METERS.

Inch	Meters.	Inch	Meters.	Inch	Meters.	Inch	Meters.
1	.0254	26	.6604	51	1.2954	76	1.9304
2	.0508	27	.6858	52	1.3208	77	1.9558
3	.0762	28	.7112	53	1.3462	78	1.9812
4	.1016	29	.7366	54	1.3716	79	2.0066
5	.127	30	.762	55	1.397	80	2.032
6	.1524	31	.7874	56	1.4224	81	2.0574
7	.1778	32	.8128	57	1.4478	82	2.0828
8	.2032	33	.8382	58	1.4732	83	2.1082
9	.2286	34	.8636	59	1.4986	84	2.1336
10	.254	35	.889	60	1.524	85	2.159
11	.2794	36	.9144	61	1.5494	86	2.1844
12	.3048	37	.9398	62	1.5748	87	2.2098
13	.3302	38	.9652	63	1.6002	88	2.2352
14	.3556	39	.9906	64	1.6256	89	2.2606
15	.381	40	1.016	65	1.651	90	2.286
16	.4064	41	1.0414	66	1.6764	91	2.3114
17	.4318	42	1.0668	67	1.7018	92	2.3368
18	.4572	43	1.0922	68	1.7272	93	2.3622
19	.4826	44	1.1176	69	1.7526	94	2.3876
20	.508	45	1.143	70	1.778	95	2.413
21	.5334	46	1.1684	71	1.8034	96	2.4384
22	.5588	47	1.1938	72	1.8288	97	2.4638
23	.5842	48	1.2192	73	1.8542	98	2.4892
24	.6096	49	1.2446	74	1.8796	99	2.5146
25	.635	50	1.27	75	1.905	100	2.540

**METRIC MEASURES WITH ENGLISH
EQUIVALENTS.**

MILLIMETERS IN INCHES.

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
1	0.0394	26	1.0236	51	2.008	76	2.992
2	0.0788	27	1.063	52	2.047	77	3.0314
3	0.1182	28	1.102	53	2.0865	78	3.0708
4	0.1575	29	1.141	54	2.126	79	3.11
5	0.197	30	1.181	55	2.165	80	3.1496
6	0.2363	31	1.22	56	2.2046	81	3.189
7	0.2756	32	1.26	57	2.244	82	3.2283
8	0.315	33	1.30	58	2.283	83	3.2677
9	0.3543	34	1.338	59	2.3227	84	3.307
10	0.3937	35	1.3778	60	2.362	85	3.3464
11	0.433	36	1.417	61	2.401	86	3.3858
12	0.4724	37	1.4565	62	2.441	87	3.4252
13	0.512	38	1.496	63	2.48	88	3.4645
14	0.551	39	1.535	64	2.52	89	3.504
15	0.59	40	1.575	65	2.559	90	3.5433
16	0.63	41	1.614	66	2.598	91	3.5826
17	0.669	42	1.653	67	2.6378	92	3.622
18	0.7086	43	1.6928	68	2.677	93	3.6614
19	0.748	44	1.732	69	2.7165	94	3.7007
20	0.7874	45	1.7715	70	2.7559	95	3.74
21	0.8267	46	1.811	71	2.7952	96	3.779
22	0.866	47	1.85	72	2.8346	97	3.819
23	0.9055	48	1.89	73	2.874	98	3.858
24	0.945	49	1.929	74	2.9134	99	3.8976
25	0.984	50	1.968	75	2.9527	100	3.937

**ENGLISH MEASURES WITH METRIC
EQUIVALENTS.**

FEET IN METERS.

Ft.	Meters.	Ft.	Meters.	Ft.	Meters.	Ft.	Meters.
1	.3048	26	7.9248	51	15.5448	76	23.1648
2	.6096	27	8.2296	52	15.8496	77	23.4696
3	.9144	28	8.5344	53	16.1544	78	23.7744
4	1.2192	29	8.8392	54	16.4592	79	24.0792
5	1.524	30	9.144	55	16.764	80	24.384
6	1.8288	31	9.4488	56	17.0688	81	24.6888
7	2.1336	32	9.7536	57	17.3736	82	24.9936
8	2.4384	33	10.0584	58	17.6784	83	25.2984
9	2.7432	34	10.3632	59	17.9832	84	25.6032
10	3.048	35	10.668	60	18.288	85	25.908
11	3.3528	36	10.9728	61	18.5928	86	26.2128
12	3.6576	37	11.2776	62	18.8976	87	26.5176
13	3.9624	38	11.5824	63	19.2024	88	26.8224
14	4.2672	39	11.8872	64	19.5072	89	27.1272
15	4.572	40	12.192	65	19.812	90	27.432
16	4.8768	41	12.4968	66	20.1168	91	27.7368
17	5.1816	42	12.8016	67	20.4216	92	28.0416
18	5.4864	43	13.1064	68	20.7264	93	28.3464
19	5.7912	44	13.4112	69	21.0312	94	28.6512
20	6.096	45	13.716	70	21.336	95	28.956
21	6.4008	46	14.0208	71	21.6408	96	29.2608
22	6.7056	47	14.3256	72	21.9456	97	29.5656
23	7.0104	48	14.6304	73	22.2504	98	29.8704
24	7.3152	49	14.9352	74	22.5552	99	30.1752
25	7.62	50	15.24	75	22.86	100	30.48

METRIC MEASURES WITH ENGLISH EQUIVALENTS.

METERS IN FEET.

Mtrs.	Feet.	Mtrs.	Feet.	Mtrs.	Feet.	Mtrs.	Feet.
1	3.2809	26	85.3034	51	167.3258	76	249.3483
2	6.5618	27	88.5843	52	170.6067	77	252.6292
3	9.8427	28	91.8652	53	173.8876	78	255.9101
4	13.1236	29	95.1461	54	177.1685	79	259.191
5	16.4045	30	98.427	55	180.4494	80	262.4719
6	19.6854	31	101.7079	56	183.7303	81	265.7528
7	22.9663	32	104.9888	57	187.0112	82	269.0337
8	26.2472	33	108.2697	58	190.2921	83	272.3146
9	29.5281	34	111.5506	59	193.573	84	275.5955
10	32.809	35	114.8315	60	196.8539	85	278.8764
11	36.0899	36	118.1124	61	200.1348	86	282.1573
12	39.3708	37	121.3933	62	203.4157	87	285.4362
13	42.6517	38	124.6742	63	206.6966	88	288.7191
14	45.9326	39	127.9551	64	209.9775	89	292.
15	49.2135	40	131.236	65	213.2584	90	295.2809
16	52.4944	41	134.5169	66	216.5393	91	298.5618
17	55.7753	42	137.7978	67	219.8202	92	301.8427
18	59.0562	43	141.0787	68	223.1011	93	305.1236
19	62.3371	44	144.3596	69	226.382	94	308.4045
20	65.618	45	147.6405	70	229.6629	95	311.6854
21	68.8989	46	150.9214	71	232.9438	96	314.9663
22	72.1798	47	154.2023	72	236.2247	97	318.2472
23	75.4607	48	157.4832	73	239.5056	98	321.5281
24	78.7416	49	160.7641	74	242.7865	99	324.809
25	82.0225	50	164.045	75	246.0674	100	328.0899

**ENGLISH MEASURES WITH METRIC
EQUIVALENTS.**

SQUARE FEET IN SQUARE METERS.

Sq. Ft.	Sq. Meters.	Sq. Ft.	Sq. Meters.	Sq. Ft.	Sq. Meters.	Sq. Ft.	Sq. Meters.
1	.0929	26	2.4154	51	4.7379	76	7.0604
2	.1858	27	2.5083	52	4.8308	77	7.1533
3	.2787	28	2.6012	53	4.9237	78	7.2462
4	.3716	29	2.6941	54	5.0166	79	7.3391
5	.4645	30	2.787	55	5.1095	80	7.432
6	.5574	31	2.8799	56	5.2024	81	7.5249
7	.6503	32	2.9728	57	5.2953	82	7.6178
8	.7432	33	3.0657	58	5.3882	83	7.7107
9	.8361	34	3.1586	59	5.4811	84	7.8036
10	.929	35	3.2515	60	5.574	85	7.8965
11	1.0219	36	3.3444	61	5.6669	86	7.9894
12	1.1148	37	3.4373	62	5.7598	87	8.0823
13	1.2077	38	3.5302	63	5.8527	88	8.1752
14	1.3006	39	3.6231	64	5.9456	89	8.2681
15	1.3935	40	3.716	65	6.0385	90	8.361
16	1.4864	41	3.8089	66	6.1314	91	8.4539
17	1.5793	42	3.9018	67	6.2243	92	8.5468
18	1.6722	43	3.9947	68	6.3172	93	8.6397
19	1.7651	44	4.0876	69	6.4101	94	8.7326
20	1.858	45	4.1805	70	6.503	95	8.8255
21	1.9509	46	4.2734	71	6.5959	96	8.9184
22	2.0438	47	4.3663	72	6.6888	97	9.0113
23	2.1367	48	4.4592	73	6.7817	98	9.1042
24	2.2296	49	4.5521	74	6.8746	99	9.1971
25	2.3225	50	4.645	75	6.9675	100	9.29

METRIC MEASURES WITH ENGLISH EQUIVALENTS.

SQUARE METERS IN SQUARE FEET.

M. S.	Sq. Ft.	S. S.	Sq. Ft.	M. S.	Sq. Ft.	M. S.	Sq. Ft.
1	10.764	26	279.872	51	548.979	76	818.087
2	21.528	27	290.636	52	559.744	77	828.851
3	32.293	28	301.40	53	570.508	78	839.615
4	43.057	29	312.165	54	581.272	79	850.38
5	53.821	30	322.929	55	592.036	80	861.144
6	64.586	31	333.693	56	602.8	81	871.908
7	75.35	32	344.458	57	613.565	82	882.673
8	86.114	33	355.222	58	624.329	83	893.436
9	96.879	34	365.986	59	635.094	84	904.207
10	107.643	35	376.75	60	645.858	85	914.965
11	118.407	36	387.545	61	656.622	86	925.73
12	129.172	37	398.279	62	667.387	87	936.494
13	139.936	38	409.043	63	678.151	88	947.258
14	150.7	39	419.808	64	688.915	89	958.023
15	161.464	40	430.572	65	699.679	90	968.787
16	172.229	41	441.336	66	710.444	91	979.551
17	182.993	42	452.10	67	721.208	92	990.316
18	193.757	43	462.865	68	731.971	93	1001.08
19	204.522	44	473.629	69	742.736	94	1011.844
20	215.286	45	484.393	70	753.501	95	1022.608
21	226.05	46	495.158	71	764.265	96	1033.373
22	236.815	47	505.922	72	775.03	97	1044.137
23	247.579	48	516.686	73	785.794	98	1054.901
24	258.343	49	527.45	74	796.558	99	1065.666
25	269.107	50	638.215	75	807.322	100	1076.43

**ENGLISH MEASURES WITH METRIC
EQUIVALENTS.**

POUNDS IN KILOGRAMS.

Lbs.	Kilograms.	Lbs.	Kilograms.	Lbs.	Kilograms.	Lbs.	Kilograms.
1	.453591	26	11.793418	51	23.133243	76	34.473068
2	.907186	27	12.247011	52	23.586836	77	34.926661
3	1.360779	28	12.700604	53	24.040429	78	35.380254
4	1.814372	29	13.154197	54	24.494022	79	35.833847
5	2.267965	30	13.60779	55	24.947615	80	36.28744
6	2.721558	31	14.061383	56	25.401208	81	36.741033
7	3.175151	32	14.514976	57	25.854801	82	37.194626
8	3.628744	33	14.968569	58	26.308394	83	37.648219
9	4.082337	34	15.422162	59	26.761987	84	38.101812
10	4.53593	35	15.875755	60	27.21558	85	38.555405
11	4.989523	36	16.329348	61	27.669173	86	39.008998
12	5.443116	37	16.782941	62	28.122766	87	39.462591
13	5.896709	38	17.236534	63	28.576359	88	39.916184
14	6.350302	39	17.690127	64	29.029952	89	40.369777
15	6.803895	40	18.14372	65	29.483545	90	40.82337
16	7.257488	41	18.597313	66	29.937138	91	41.276963
17	7.711081	42	19.050906	67	30.390731	92	41.730556
18	8.164674	43	19.504499	68	30.844324	93	42.184149
19	8.618267	44	19.958092	69	31.297917	94	42.637742
20	9.07186	45	20.411685	70	31.75151	95	43.091335
21	9.525453	46	20.865278	71	32.205103	96	43.544928
22	9.979046	47	21.318871	72	32.658696	97	43.998521
23	10.432639	48	21.772464	73	33.112289	98	44.452114
24	10.886232	49	22.226057	74	33.565882	99	44.905707
25	11.339825	50	22.67965	75	34.019475	100	45.3593

**METRIC MEASURES WITH ENGLISH
EQUIVALENTS.**

KILOGRAMS IN POUNDS.

Kg.	Pounds.	Kg.	Pounds.	Kg.	Pounds.	Kg.	Pounds.
1	2.205	26	57.320	51	112.435	76	167.550
2	4.409	27	59.524	52	114.639	77	169.754
3	6.614	28	61.729	53	116.844	78	171.959
4	8.818	29	63.933	54	119.048	79	174.163
5	11.023	30	66.138	55	121.253	80	176.368
6	13.228	31	68.343	56	123.458	81	178.573
7	15.432	32	70.547	57	125.662	82	180.777
8	17.637	33	72.752	58	127.867	83	182.982
9	19.841	34	74.956	59	130.071	84	185.186
10	22.046	35	77.161	60	132.276	85	187.391
11	24.251	36	79.366	61	134.481	86	189.596
12	26.455	37	81.570	62	136.685	87	191.800
13	28.660	38	83.775	63	138.890	88	194.005
14	30.864	39	85.979	64	141.094	89	196.209
15	33.069	40	88.184	65	143.299	90	198.414
16	35.274	41	90.389	66	145.504	91	200.619
17	37.478	42	92.593	67	147.708	92	202.823
18	39.683	43	94.798	68	149.913	93	205.028
19	41.887	44	97.002	69	152.117	94	207.232
20	44.092	45	99.207	70	154.322	95	209.437
21	46.297	46	101.412	71	156.527	96	211.642
22	48.501	47	103.616	72	158.731	97	213.846
23	50.706	48	105.821	73	160.936	98	216.051
24	52.910	49	108.025	74	163.140	99	218.255
25	55.115	50	110.230	75	165.345	100	220.460

**ENGLISH MEASURES WITH METRIC
EQUIVALENTS.**

GALLONS (of 231 cu. in.) IN LITERS.

Gal.	Liters.	Gal.	Liters.	Gal.	Liters.	Gal.	Liters.
1	3.785	26	98.41	51	193.035	76	287.66
2	7.57	27	102.195	52	196.82	77	291.445
3	11.355	28	105.98	53	200.605	78	295.23
4	15.14	29	109.765	54	204.39	79	299.015
5	18.925	30	113.55	55	208.175	80	302.8
6	22.71	31	117.335	56	211.96	81	306.585
7	26.495	32	121.12	57	215.745	82	310.37
8	30.28	33	124.905	58	219.53	83	314.155
9	34.065	34	128.69	59	223.315	84	317.94
10	37.85	35	132.475	60	227.1	85	321.725
11	41.635	36	136.26	61	230.885	86	325.51
12	45.42	37	140.045	62	234.67	87	329.295
13	49.205	38	143.83	63	238.455	88	333.08
14	52.99	39	147.615	64	242.24	89	336.865
15	56.775	40	151.4	65	246.025	90	340.65
16	60.56	41	155.185	66	249.81	91	344.435
17	64.345	42	158.97	67	253.595	92	348.22
18	68.13	43	162.755	68	257.38	93	352.005
19	71.915	44	166.54	69	261.165	94	355.79
20	75.7	45	170.32	70	264.95	95	359.575
21	79.485	46	174.11	71	268.735	96	363.36
22	83.27	47	177.895	72	272.52	97	367.145
23	87.055	48	181.68	73	276.305	98	370.93
24	90.84	49	185.465	74	280.09	99	374.715
25	94.625	50	189.25	75	283.875	100	378.5

**METRIC MEASURES WITH ENGLISH
EQUIVALENTS.**

LITERS IN GALLONS OF 231 CUBIC INCHES.

Liters.	Gallons.	Liters.	Gallons.	Liters.	Gallons.	Liters.	Gallons.
1	.2642	26	6.8683	51	13.4724	76	20.0765
2	.5283	27	7.1324	52	13.7366	77	20.3407
3	.7925	28	7.3966	53	14.0007	78	20.6048
4	1.0567	29	7.6608	54	14.2649	79	20.8690
5	1.3208	30	7.9249	55	14.5290	80	21.1332
6	1.5850	31	8.1891	56	14.7932	81	21.3973
7	1.8491	32	8.4533	57	15.0574	82	21.6615
8	2.1133	33	8.7174	58	15.3215	83	21.9256
9	2.3775	34	8.9816	59	15.5857	84	22.1898
10	2.6416	35	9.2458	60	15.8499	85	22.4540
11	2.9058	36	9.5099	61	16.1140	86	22.7181
12	3.1700	37	9.7741	62	16.3782	87	22.9823
13	3.4341	38	10.0382	63	16.6424	88	23.2465
14	3.6983	39	10.3024	64	16.9065	89	23.5106
15	3.9625	40	10.5666	65	17.1707	90	23.7748
16	4.2266	41	10.8307	66	17.4349	91	24.0390
17	4.4908	42	11.0949	67	17.6990	92	24.3031
18	4.7550	43	11.3591	68	17.9632	93	24.5673
19	5.0191	44	11.6232	69	18.2273	94	24.8315
20	5.2833	45	11.8874	70	18.4915	95	25.0956
21	5.5475	46	12.1516	71	18.7557	96	25.3598
22	5.8116	47	12.4157	72	19.0198	97	25.6240
23	6.0758	48	12.6799	73	19.2840	98	25.8881
24	6.3399	49	12.9441	74	19.5482	99	26.1523
25	6.6041	50	13.2082	75	19.8123	100	26.4164

The International Metric Screw Thread.

The International Congress for the Standardization of Screw Threads, held at Zurich, Switzerland, October 2-4, 1898, recommend that the thread section of the proposed international thread should have its sides at an angle of 60 degrees and the top and bottom of the thread flattened $\frac{1}{8}$ the pitch, making the limiting conditions exactly the same as the United States, Standard thread. The system of pitches recommended, is nearly the same as one established by the Society for the Encouragement of National Industries.

The system is known under the name of International System (System International. S. I.)

The clearance of one-sixteenth the height of the original thread triangle, permits the use of either flat or rounded threads on the taps as the mean thread diameter is the same in either case.

7

Pitch —

Number threads to one mm.

Depth = $P \times .6495$

Flat = $\frac{P}{8}$

Nominal Diameter of Screw.

Pitch.

Millimeters	Inches.	Nearest 64ths	Millimeters.	Inches.
6	.236	$\frac{15}{64}$ +	1	.0394
7	.275	$\frac{17}{64}$ -	1	.0394
8	.315	$\frac{19}{64}$ +	1 $\frac{1}{4}$	.0492
9	.354	$\frac{21}{64}$ -	1 $\frac{1}{4}$	.0492
10	.394	$\frac{23}{64}$ +	1 $\frac{3}{4}$	.0590
11	.433	$\frac{25}{64}$ -	1 $\frac{3}{4}$	.0590
12	.472	$\frac{27}{64}$ +	1 $\frac{7}{8}$	.0689
14	.551	$\frac{35}{64}$ +	2	.0787
16	.630	$\frac{5}{8}$ +	2	.0787
18	.709	$\frac{45}{64}$ +	2 $\frac{1}{4}$	.0984
20	.787	$\frac{47}{64}$ +	2 $\frac{1}{4}$	.0984
22	.866	$\frac{51}{64}$ +	2 $\frac{1}{2}$	.0984
24	.945	$\frac{15}{16}$ +	3	.1181
27	1.063	$1\frac{1}{16}$ +	3	.1181
30	1.181	$1\frac{5}{16}$ +	3 $\frac{1}{2}$	.1378
33	1.299	$1\frac{13}{16}$ +	3 $\frac{1}{2}$	.1378
36	1.416	$1\frac{27}{32}$ -	4	.1575
39	1.535	$1\frac{31}{32}$ +	4	.1575
42	1.653	$1\frac{33}{32}$ -	4 $\frac{1}{4}$	.1772
45	1.772	$1\frac{35}{32}$ +	4 $\frac{1}{4}$	.1772
48	1.890	$1\frac{37}{32}$ -	5	.1968
52	2.047	$2\frac{3}{64}$ +	5	.1968
56	2.204	$2\frac{11}{64}$ +	5 $\frac{1}{2}$	.2165
60	2.362	$2\frac{23}{64}$ +	5 $\frac{1}{2}$	.2165
64	2.520	$2\frac{25}{64}$ +	6	.2362
68	2.677	$2\frac{27}{64}$ +	6	.2362
72	2.835	$2\frac{51}{64}$ -	6 $\frac{1}{2}$	.2559
76	2.992	$2\frac{53}{64}$ +	6 $\frac{1}{2}$	.2559
80	3.150	$3\frac{5}{64}$ -	7	.2756

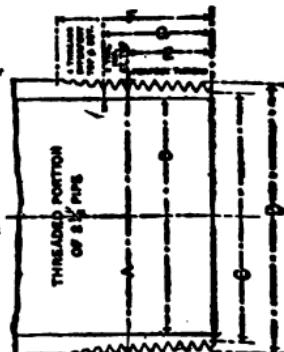
Approximate
Number of
Threads
per Inch.

Tap Drill Size.

Millimeters.	Inches.	Nearest $\frac{1}{64}$ in.
4 $\frac{1}{8}$	.185	$\frac{1}{8}$ -
5 $\frac{1}{16}$	.224	$\frac{1}{16}$ +
6 $\frac{1}{8}$	.251	$\frac{1}{8}$ +
7 $\frac{1}{16}$	.290	$\frac{1}{8}$ -
8 $\frac{1}{32}$	.317	$\frac{1}{16}$ +
9 $\frac{1}{32}$	.356	$\frac{1}{8}$ -
9 $\frac{1}{16}$	.383	$\frac{1}{8}$ +
11 $\frac{1}{16}$	.449	$\frac{1}{8}$ -
13 $\frac{1}{16}$	.528	$\frac{1}{8}$ -
14 $\frac{1}{16}$	.581	$\frac{1}{8}$ +
16 $\frac{1}{16}$	.659	$\frac{1}{8}$ +
18 $\frac{1}{16}$	.738	$\frac{1}{8}$ +
20 $\frac{1}{16}$	.791	$\frac{1}{8}$ -
23 $\frac{1}{16}$	.910	$\frac{1}{8}$ +
25 $\frac{1}{32}$	1.002	1 +
28 $\frac{1}{32}$	1.120	1 $\frac{1}{16}$ +
30 $\frac{1}{16}$	1.212	1 $\frac{1}{8}$ -
33 $\frac{1}{16}$	1.330	1 $\frac{1}{8}$ +
36 $\frac{1}{32}$	1.423	1 $\frac{1}{16}$ +
39 $\frac{1}{32}$	1.542	1 $\frac{1}{8}$ -
41 $\frac{1}{16}$	1.634	1 $\frac{1}{8}$ -
45 $\frac{1}{16}$	1.791	1 $\frac{1}{8}$ -
48 $\frac{1}{32}$	1.923	1 $\frac{1}{16}$ +
52 $\frac{1}{32}$	2.083	2 $\frac{1}{16}$ +
56 $\frac{1}{16}$	2.213	2 $\frac{1}{8}$ -
60 $\frac{1}{16}$	2.370	2 $\frac{1}{8}$ -
63 $\frac{1}{16}$	2.500	2 $\frac{1}{8}$ +
67 $\frac{1}{16}$	2.660	2 $\frac{1}{8}$ +
70 $\frac{1}{16}$	2.791	2 $\frac{1}{8}$ +

Standard Pipe and Pipe Threads.

STANDARD PIPE AND PIPE THREADS.



A — outside diameter of perfect thread.

B — inside diameter of pipe.

C = root diameter of thread at end of pipe.

D = outside diameter of thread at end of pipe.

E — length of perfect thread.

F — total length of thread.

G — length of perfect thread plus two threads.

BRIGGS' FORMULA.

E — perfect thread — $(4.8 + 0.8 A) P$.

P — pitch of thread — $\frac{1}{N}$.

N — number of threads.

F — length of taper at top.

Taper $\frac{3}{4}''$ to one foot.

Height of thread — $8 \frac{1}{N}$.

G — length of taper at bottom.

Size.	Thread.	P					
		A	B	C	D	E	F
1	27	.405	.270	.334	.393	.19	.41
1	18	.540	.364	.433	.522	.29	.62
1	18	.675	.494	.567	.656	.30	.63
1	14	.840	.623	.702	.816	.39	.82
1	14	1.050	.824	.911	1.025	.40	.546
1	11 ¹ ₄	1.315	1.046	1.144	1.283	.51	1.03
1 ¹ ₂	11 ¹ ₄	1.660	1.380	1.488	1.627	.54	1.06
1 ¹ ₁	11 ¹ ₄	1.900	1.611	1.727	1.866	.55	1.07
2	11 ¹ ₄	2.375	2.067	2.200	2.339	.58	1.10
2 ¹	2 ¹	2.875	2.468	2.618	2.818	.89	1.64
3	3 ¹	3.500	3.067	3.243	3.443	.95	1.70
3 ¹	4 ¹	4.000	3.548	3.738	3.938	1.00	1.75
4	4 ¹	4.500	4.026	4.233	4.443	1.05	1.80
4 ¹	5 ¹	5.000	4.508	4.733	4.933	1.10	1.85
5	5 ¹	5.663	5.045	5.289	5.489	1.16	1.91
5 ¹	6 ¹	6.625	6.065	6.347	6.547	1.26	2.01
6	7 ¹	7.625	7.023	7.349	7.540	1.36	2.11
7	8 ¹	8.625	7.981	8.332	8.532	1.46	2.21
8	9 ¹	9.625	8.937	9.324	9.524	1.56	2.31
9	10 ¹	10.750	10.019	10.445	10.645	1.675	2.425
10	11 ¹ ₄	12.000	11.224	11.694	11.894	1.80	2.55
11	12 ¹ ₄	13.000	12.180	12.685	12.885	1.90	2.65
12							2.160

Circumferences of Circles.

These tables are arranged to give all circumferences between $\frac{1}{4}$ inch and $100\frac{3}{4}$ inches, varying by $\frac{1}{4}$. The whole numbers are at the left, fractions at the top. The first column gives circumferences of even inches, as, beside 11 is 34.558. For $11\frac{3}{4}$ inches follow the same line to the last column, marked $\frac{3}{4}$ at the top and find 36.914. The circumference of a $\frac{1}{2}$ -inch circle is 1.571 inches. These can be used for inches, feet, yards, or meters by remembering that if you look for the circumference of a 7-foot circle the answers are in feet instead of inches.

CIRCUMFERENCES OF CIRCLES.

		$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
	.....	.785	1.571	2.356
1	3.1416	3.927	4.712	5.498
2	6.282	7.068	7.854	8.639
3	9.425	10.21	10.996	11.781
4	12.566	13.352	14.137	14.923
5	15.708	16.493	17.279	18.064
6	18.850	19.635	20.42	21.206
7	21.991	22.776	23.562	24.347
8	25.133	25.918	26.704	27.489
9	28.274	29.06	29.845	30.631
10	31.416	32.201	32.987	33.772
11	34.558	35.343	36.128	36.914
12	37.699	38.485	39.27	40.055
13	40.841	41.626	42.412	43.197
14	43.982	44.768	45.553	46.338
15	47.124	47.909	48.695	49.480
16	50.265	51.051	51.836	52.622
17	53.407	54.192	54.978	55.763
18	56.549	57.334	58.119	58.905
19	59.69	60.476	61.261	62.046
20	62.832	63.617	64.403	65.188
21	65.973	66.759	67.544	68.33
22	69.115	69.9	70.686	71.471
23	72.257	73.042	73.827	74.613
24	75.398	76.184	76.969	77.754
25	78.54	79.325	80.111	80.896
26	81.681	82.467	83.252	84.038
27	84.823	85.608	86.394	87.179
28	87.965	88.75	89.535	90.321
29	91.106	91.892	92.677	93.462
30	94.248	95.033	95.819	96.604
31	97.389	98.175	98.96	99.746
32	100.531	101.316	102.102	102.887
33	103.673	104.458	105.243	106.029
34	106.814	107.6	108.385	109.17
35	109.956	110.741	111.527	112.312
36	113.097	113.883	114.668	115.454

CIRCUMFERENCES OF CIRCLES.

		X	X ₂	X ₄
37	116.239	117.024	117.81	118.596
38	119.301	120.166	120.951	121.737
39	122.522	123.308	124.093	124.878
40	125.664	126.449	127.235	128.02
41	128.805	129.591	130.376	131.161
42	131.947	132.732	133.518	134.303
43	135.088	135.874	136.659	137.445
44	138.23	139.015	139.801	140.586
45	141.372	142.157	142.942	143.728
46	144.513	145.299	146.084	146.869
47	147.655	148.44	149.266	150.011
48	150.796	151.582	152.367	153.153
49	153.938	154.723	155.509	156.294
50	157.08	157.865	158.65	159.436
51	160.221	161.007	161.792	162.577
52	163.363	164.148	164.934	165.719
53	166.504	167.29	168.075	168.861
54	169.646	170.431	171.217	172.002
55	172.788	173.573	174.358	175.144
56	175.929	176.715	177.5	178.285
57	179.071	179.856	180.642	181.427
58	182.212	182.998	183.783	184.569
59	185.354	186.139	186.925	187.71
60	188.496	189.281	190.066	190.852
61	191.637	192.423	193.208	193.993
62	194.779	195.564	196.35	197.135
63	197.92	198.706	199.491	200.277
64	201.062	201.847	202.633	203.418
65	204.204	204.989	205.774	206.56
66	207.345	208.131	208.916	209.701
67	210.487	211.272	212.058	212.843
68	213.628	214.414	215.199	215.984
69	216.77	217.555	218.341	219.126
70	219.911	220.697	221.482	222.268
71	223.053	223.838	224.624	225.409
72	226.195	226.98	227.765	228.551
73	229.336	230.122	230.907	231.692

CIRCUMFERENCES OF CIRCLES.

		$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
74	232.478	233.263	234.049	234.834
75	235.619	236.405	237.19	237.976
76	238.761	239.546	240.332	241.117
77	241.903	242.688	243.473	244.259
78	245.044	245.83	246.615	247.4
79	248.186	248.971	249.757	250.542
80	251.327	252.113	252.898	253.684
81	254.469	255.254	256.04	256.825
82	257.611	258.396	259.181	259.967
83	260.752	261.538	262.323	263.108
84	263.894	264.679	265.465	266.250
85	267.035	267.821	268.606	269.392
86	270.177	270.962	271.748	272.533
87	273.319	274.104	274.889	275.675
88	276.46	277.246	278.031	278.816
89	279.602	280.387	281.173	281.958
90	282.743	283.529	284.314	285.1
91	285.885	286.67	287.456	288.241
92	289.027	289.812	290.597	291.383
93	292.168	292.954	293.739	294.524
94	295.31	296.095	296.881	297.666
95	298.451	299.237	300.022	300.807
96	301.593	302.378	303.164	303.949
97	304.734	305.52	306.305	307.091
98	307.876	308.661	309.447	310.232
99	311.018	311.803	312.588	313.374
100	314.159	314.944	315.729	316.515

Areas of Circles.

These tables are arranged to give areas of all circles from $\frac{1}{4}$ inch diameter to $100\frac{3}{4}$ inches. The whole numbers are at the left, fractions at the top. The first column gives the areas of even inches, as, beside 17 is the area 226.98 square inches. For $17\frac{3}{4}$ inches follow the same line to the last column, marked $\frac{3}{4}$ at the top, and find 247.45. The area of a $\frac{1}{2}$ -inch circle is .1963 square inch.

These can be used for inches, feet, yards or meters by remembering that if you look for the area of a 7-foot circle the answer is square feet instead of inches.

AREAS OF CIRCLES.

		$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
1	.....	.0491	.1963	.4418
2	.7854	1.2272	1.7671	2.4053
3	3.1416	3.9761	4.9087	5.9396
4	7.0686	8.2958	9.6211	11.045
5	12.566	14.186	15.904	17.728
6	19.635	21.648	23.758	25.967
7	28.274	30.68	33.183	35.785
8	38.485	41.282	44.179	47.173
9	50.265	53.456	56.745	60.132
10	63.617	67.201	70.882	74.662
11	78.54	82.516	86.59	90.763
12	95.033	99.402	103.87	108.43
13	113.1	117.86	122.72	127.68
14	132.73	137.89	143.14	148.49
15	153.94	159.48	165.13	170.87
16	176.71	182.65	188.69	194.83
17	201.06	207.39	213.82	220.35
18	226.98	233.71	240.53	247.45
19	254.47	261.59	268.8	276.12
20	283.53	291.04	298.65	306.35
21	314.16	322.06	330.06	338.16
22	346.36	354.66	363.05	371.54
23	380.13	388.82	397.61	406.49
24	415.48	424.56	433.74	443.01
25	452.39	461.86	471.44	481.11
26	490.87	500.74	510.71	520.77
27	530.93	541.19	551.55	562.
28	572.56	583.21	593.96	604.81
29	615.75	626.8	637.94	649.18
30	660.52	671.96	683.49	695.13
31	706.86	718.69	730.62	742.64
32	754.77	766.99	779.31	791.73
33	804.25	816.86	829.58	842.39
34	855.3	868.31	881.41	894.62
35	907.92	921.32	934.82	948.42
36	962.11	975.91	989.80	1003.8
	1017.9	1032.1	1046.3	1060.7

AREAS OF CIRCLES.

		X	X	X
37	1075.2	1089.8	1104.5	1119.2
38	1134.1	1149.1	1164.2	1179.3
39	1194.6	1210.	1225.4	1341.
40	1256.6	1272.4	1288.2	1304.2
41	1320.3	1336.4	1352.7	1269.
42	1385.4	1402.	1418.6	1435.4
43	1452.2	1469.1	1486.2	1503.3
44	1520.5	1537.9	1555.3	1572.8
45	1590.4	1608.2	1626.	1643.9
46	1661.9	1680.	1698.2	1716.5
47	1734.9	1753.5	1772.1	1790.8
48	1809.6	1828.5	1847.5	1866.5
49	1885.7	1905.	1924.4	1943.9
50	1963.5	1983.2	2003.	2022.8
51	2042.8	2062.9	2083.1	2103.3
52	2123.7	2144.2	2164.8	2185.4
53	2206.2	2227.	2248.	2269.1
54	2290.2	2311.5	2332.8	2354.3
55	2375.8	2397.5	2419.2	2441.1
56	2463.	2485.	2507.2	2529.4
57	2551.8	2574.2	2596.7	2619.4
58	2642.1	2664.9	2687.8	2710.9
59	2734.	2757.2	2780.5	2803.9
60	2827.4	2851.	2874.8	2898.6
61	2922.5	2946.5	2970.6	2994.8
62	3019.1	3043.5	3068.	3092.6
63	3117.2	3142.	3166.9	3191.9
64	3217.	3242.2	3267.5	3292.8
65	3318.3	3343.9	3369.6	3395.3
66	3421.2	3447.2	3473.2	3499.4
67	3525.7	3552.	3578.5	3605.
68	3631.7	3658.4	3685.3	3712.2
69	3739.3	3766.4	3793.7	3821.
70	3848.5	3786.	3903.6	3931.4
71	3959.2	3987.1	4015.2	4043.3
72	4071.5	4099.8	4128.2	4156.8
73	4185.4	4214.1	4242.9	4271.8

AREAS OF CIRCLES.

		X	Y	Z
74	4300.8	4329.9	4359.2	4388.5
75	4417.9	4447.4	4477.	4506.7
76	4536.5	4566.4	4596.3	4626.4
77	4656.6	4686.9	4717.3	4747.8
78	4778.4	4809.	4839.8	4870.7
79	4901.7	4932.7	4963.9	4995.2
80	5026.5	5058.	5089.6	5121.2
81	5153.	5184.9	5216.8	5248.9
82	5281.	5313.3	5345.6	5378.1
83	5410.6	5443.3	5476.	5508.8
84	5541.8	5574.8	5607.9	5641.2
85	5674.5	5707.9	5741.5	5775.1
86	5808.8	5842.6	5876.5	5910.6
87	5944.7	5978.9	6013.2	6047.6
88	6082.1	6116.7	6151.4	6186.2
89	6221.1	6256.1	6291.2	6326.4
90	6361.7	6397.1	6432.6	6468.2
91	6503.9	6539.7	6575.5	6611.5
92	6647.6	6683.8	6720.1	6756.4
93	6792.9	6829.5	6866.1	6902.9
94	6939.8	6976.7	7013.8	7051.
95	7088.	7125.6	7163.	7200.6
96	7238.2	7276.	7313.8	7351.8
97	7389.8	7428.	7466.2	7504.5
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